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A REPORT ON THE UTILITY OF LIVESTOCK AND VEHICULAR UNDERPASSES



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FINAL REPORT

LIVESTOCK AND VEHICULAR UNDERPASSES

By

A. A. Jones

Right of Way Division

Prepared for

Montana State Highway Commission

Planning Survey Section

In cooperation with
U. S. Department of Transportation
Federal Highway Administration

The opinions, findings, conclusions and recommendations expressed
in this publication are those of the author and not necessarily
those of the Federal Highway Administration.

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A B S T R A C T

LIVESTOCK AND VEHICULAR UNDERPASSES

By office review of design and construction details, and by interview of property owners, information can be compiled on the utility of installed machinery and cattle passes; whether, for a given farm or ranch operation, the designs are adequate, sub-standard or super-adequate. This will give data and support to acquisition personnel for convincing landowners that proposed designs will meet the needs and will give design personnel data on which to base their size calculations so needs are adequately met. It should be possible to find comparable livestock units from the compiled case studies to aid in selecting an adequate structure in a given situation. We quite definitely know a small stockpass of excessive length is very undesirable, particularly those located in drainage areas. Topographical location seems to be the most influential variable, given an acceptable size of stockpass.

ACKNOWLEDGMENTS

The research project was undertaken by the Right of Way Division with R. E. Champion, Chief Right of Way Agent, as principal investigator. J. R. Ricker, Assistant Chief Right of Way Agent, capably performed the administrative and consulting portion of the project while A. A. Jones coordinated the field research, performed the analysis, and wrote the final report. The able assistance of District Right of Way Agents: Kenneth Cress, Wes Plann, Jack Stephenson, Al Boehme, Pat Kane and Lowell Myers; and the District Right of Way Supervisors: Kevin Thomas of District 1, James Keyes of District 2, James Hein of District 3, Dean Knapp of District 4 and William Hauck of District 5, are respectfully acknowledged. The corresponding states' aid, particularly the New Mexico Highway Department's, was of special importance. The State of Mississippi, which did an extensive research project on cattlepasses with the aid of the Federal Highway Administration, also deserves acknowledgment. The Walla Walla District of the Army Corps of Engineers has a good usable underpass report, conducted in 1965 at a time when there were many questions regarding utility of underpasses.

The Right of Way Division wishes to thank all other department employees who participated in this report. It could not have been possible without the cooperation and knowledge of all those involved. It was begun on July 1, 1970 and completed on October 8, 1971 at a cost of \$17,000.00.

The key to any success this report may enjoy lies with the farmers and ranchers themselves. We believed it to be in the best interests of all to keep their names anonymous where possible. We found them to be receptive and congenial in most cases, although a few still harbor resentment towards the Highway Commission because of severance problems or other reasons. Without the cooperation we experienced, no realistic results could have been achieved in this study.

M O N T A N A H I G H W A Y C O M M I S S I O N

Right-of-Way Division

AN EVALUATION OF LIVESTOCK AND VEHICULAR UNDERPASSES

Foreword

Agriculture is among Montana's foremost industries. The stockman's roots were established in Montana history when the first herd of cattle wintered near what is now Dillon, Montana in 1856, and were sold as beef to the early miners. Texas Longhorns were trailed into the eastern part of the State beginning in 1866 - 2,500 head at a time. This marked the beginning of the cattle industry which found its profits in "free" grassland and sales of beef to gold miners and camp followers who were rapidly moving into Montana. There were also shipments of beef by rail to eastern markets. The cattle boom of the 80's then began when the range was cleared of buffalo.

"The Last of the Five Thousand", famed painting by Charles M. Russell, was the pictorial results of the severe winter of 1886-87. The results to livestock were disastrous. This, and later over-expansion of cattle production, led to hard times for many a cattle spread. The fittest and most intelligently managed outfits survived those times and today some of these ranches still bear the original name.

Father DeSmet instructed the Flathead Indians (Confederated Salish and Kootenai) in farming at St. Mary's Mission near what is now Stevensville, in 1841. This started the development of one of Montana's major resources. In 1910 a major agricultural change swept over Montana. Free land beckoned farmers much as free grass beckoned the cattlemen of earlier years. Trainloads of newcomers

rolled in and filed homestead entries on surveyed government land.

Miles City was once considered the largest horse market in the world and the demand of the Boer War caused expansion in this industry from 1895 to 1919.

The Rocky Mountains, with snow-capped peaks, forested slopes, broad valleys and many lakes, cover the agricultural western 40% of Montana; the rest of the State is high plains country primarily devoted to ranching and farming. In 1969, Montana ranked third among the states in wheat and barley output. Over 3.5 million acres of wheat were harvested for a total of 96,800,000 bushels, or an average of 27.6 bushels per acre.¹ Montana ranked fifth in sheep and twelfth in cattle that year. Farm receipts totaled 534 million dollars in 1969, more than half from livestock, with an increase of about 30 million dollars from 1968. The 1969 calf crop was 1.5 million with an indicated calving rate of about 90%. There were a total of 2.5 million cattle movements in and out of state in 1969. Central and south-central Montana showed largest cattle movements. Also during this period, 1.5 million head were shipped to out-of-state points out of a total cattle inventory of about 3 million; 38% of the 1.5 million shipment were calves.² The Montana Livestock Sanitary Board estimated about 60% of total stock are Hereford or Angus; the remaining are mixed breeds, Charolais, or Shorthorns.

This brief historical and statistical background is intended to serve as an introduction to our main purpose, researching the utility of stock and machinery pass structures through the analysis of Montana's stock and grain units after highway construction. A total of 700 miles of controlled access on Highways I-90 and I-94, east to west, and 400 miles of I-15, north to south, creates a barrier and some related problems for operators of stock and grain

units. These problems are not quite as severe on primary or secondary systems because all rights of access to the highway are not obtained. Structures of the most usable sizes will hopefully be arrived at through this study. Our vehicular transportation system has evolved from the ruts of oxcarts and covered wagons to a fenced four-lane network of national highways. If the farm and ranch industry is to evolve and adjust to these changes, we must make our effort to help keep the wheels of agriculture rolling.

Total right-of-way payments to landowners in Montana was 35% for land and 65% for damage to remainder during 1969. In 1968, the figure was 42% for land and 58% for damages. This was on the Interstate Highway System. These correspond to a 30-60 figure published by the Texas Transportation Institute.³ Primaries were closer to a 50-50 payment and secondary highways, 65% for land and 35% for damages, in Montana. This can be interpreted as the results of non-controlled access as compared to controlled access.⁴ This suggests that as much as 30% of payments to landowners on interstate systems can be the result of controlled access and accompanying highway construction problems. However, there is some 1970 information indicating all systems are evenly distributed between land and damage payments. This analysis of underpass structures will, hopefully, aid in appraising future damages as well as serve as an aid in negotiation, litigation and structure justification. The cattle and machinery underpass structures mitigate damage payments at least in the amount of the structure cost in many cases where they are economically justified. The 30% differential in damage payment between secondary systems and interstate systems tends to show the need for these land use structures which attempt to correct the basic access problems. Inquiries to other states have provided valuable insight and will be referred to later in this chapter.

One significant result of the aforementioned study recently published by the Texas Transportation Institute showed 38% of all payments for right-of-way went into savings to improve their cash position. This was the result of sampling 20 farms with an average of 140 acres per farm along the right-of-way. This might be interpreted as an indication of future uncertainty as to how the right-of-way severance will affect their unit.

The Army Corps of Engineers, Walla Walla, Washington, produced a report on Northwest Livestock Underpasses in 1965-66. The most recent study of this nature was done by the Mississippi Highway Department and completed in 1970. Mississippi is a cattle producing state. An Evaluation of Cattlepasses Under Mississippi Highways was conducted to "ensure maximum usage of structures constructed for this purpose." After investigating about 300 structures, they found that nearly one-half of these structures were in use, 30% had never been used and the remaining 21% had been used and then abandoned.⁵ They were inspected and measured to establish the use condition, size, rate the location, drainage and use, and interview the land user. The situation in Mississippi is quite different from Montana due to moisture, climate and size of ranches and farms. Mississippi did, nevertheless, establish a precedent in an important area of investigating the utility of cattlepasses. For example, their research showed that box culverts have a greater frequency of use than do arch culverts; however, only 4% of their sample showed stockpass lengths greater than 100 feet. The Montana study will explore the idea that for cattle usage, utility might be a function of length and size. For machinery use, utility appears to be a function of size, location, management and innovation.

It is well to keep in mind that all breeds of cattle, although temperamental and sometimes individualistic in nature, might be measured in volume just

like any other quantity; i.e., so many head per hour might be driven through a certain size underpass, and the number will naturally decrease with the size of opening to the point they may not use it at all.

Some of the other states have been quite helpful in structure use analysis. The following experiences were stated in letters received from various states:

Nevada undertook a study for the economic justification of cattlepasses on I-80 through Nevada, in 1967. One phase of their study was to interview affected ranches. These ranches ranged in size from a 500-head unit to a 10,000-head unit. In areas where I-80 severed the ranch, it was found that a 10' x 10' box underpass was of sufficient size to permit cattle to roam freely to and from water. In areas where the meadow and hayland were separated from the grazing land and cattle were driven from summer to winter range, a minimum size of 14' x 14' box underpass was necessary. A 20' wide and 14' high structure served the larger machinery. They mentioned an 8' wide x 10' high underpass was constructed on a skew where the cattle could not be driven through and had to be dragged by a rope. This might indicate length as a deterrent factor in proportion to this stockpass size. They also mentioned the Bureau of Land Management feels a minimum size in range country should be a 10' x 10' concrete box, but for certain areas of range management, a 14' x 14' concrete box structure is necessary. They stated that on primary and secondary highways, 7' x 7' or 8' x 7' concrete box stockpasses have been justified from a safety standpoint. A smaller size is possible when narrower roadwidths are involved.

Utah has had some interstate structures justified for farm and livestock use on a safety basis in those areas of public use where traffic count is

heavy on a county road or interchange area. They mention that courts consisting of juries or judges have ruled on several condemnation cases that the total unit should be used in justifying underpasses. Non-contiguous ownerships present a problem in Utah similar to those in Montana.

Utah recognizes the need for a minimum 10' wide x 8' high concrete box for a stock trail or for more than one user. This allows the rancher to follow the stock with a pickup. Some Utah stockmen express the opinion that where livestock can see vegetation on the other side of the highway, they will use an overpass, but not an overpass with a steep grade. At any rate, in their opinion, it is better to allow stock movement under the highway rather than over.

Arizona mentions an important aspect of maximum land utility with respect to drainage and land use structures. They say in areas where sufficient structures have been included in the construction for both cattle and drainage, (our underline) their relations with the property owners have been very satisfactory. This reaffirms a belief of some highway personnel and landowners that it is better to have separate structures. They did also mention, however, that by locating cattlepasses on the plans during the preliminary survey and engineering phase, they compounded appraisal problems to some extent. To ease this, they created a pre-reviewing unit on an engineering basis, which appears to have alleviated this and avoided problems which came up during appraisal and acquisition periods.

This investigator's personal experience leads to a preference that the same right-of-way agent should conduct the preliminary right-of-way estimate, structure justification study, and placement of each, and make the actual appraisal for purposes of continuity and consistency. This is a suggestion and not necessarily a recommendation.

The State of Washington had found it necessary to re-evaluate their policies and procedures concerning the location of cattlepasses because these features were not shown on the construction plans. By virtue of this, a with and without structure appraisal sometimes resulted in substantial savings. Under their previous policy, a statement to the effect that cattlepasses, approaches, etc., would be negotiated was a beneficial aid at public hearings and was ordinarily sufficient to satisfy the audience.

The State of Nebraska mentions they have not conducted studies of underpass structures other than to observe that the underpasses are used as intended by the adjacent landowners.

North Dakota mentions one landowner's use of large wooden doors on the north side of a 14's x 16' r structural plate pipe under I-94, to keep it from plugging with snow. However, snow removal from in front of the doors became a problem as did maintenance of the doors, primarily because of their size. They apparently alleviated some non-contiguous ownership problems through the bridge-type multiple-use structures located on county road section lines.

Wyoming has a variety of structure types but appears most successful with the concrete boxes and 3-span bridge-type machinery passes (on the Interstate System), due to the large size of the ranching units. During a telephone conversation, it was found that whereas anything smaller than a 10' x 10' box blows full of snow in the wintertime, these are regarded as highly usable during favorable weather months. The smaller units usually have smaller structures and, therefore, subsequent management problems may be more severe than the larger units. Their highway department has tried to maintain some of these boxes for wintertime usage.

The following is a quotation from the afore-mentioned stockpass report published in 1965 and revised in 1966, The Report on Survey of Northwest Livestock Underpasses, conducted by the U.S. Army Engineer District, Walla Walla, Washington.⁶

"Conclusion:

Problems associated with the passage of livestock through an underpass, whether it be constructed of metal, timber or concrete, do not seem insurmountable. The vast majority of the livestock passes investigated were serving satisfactorily or had served satisfactorily prior to discontinued use.

Recommendations:

The following design suggestions are recommended, with particular attention given to providing a firm footing and as much light as possible inside the structure:

a. Structures with beveled ends allow more light to enter the pipe; hence this practice is recommended. Stability requirements at intakes of underpasses serving also for drainage purposes may prevent use of beveled ends.

b. Underpasses that also serve as drainage structures should have permanent walking pads that will not wash or erode.

c. Structures that allow livestock access to a river whose surface fluctuates several feet a year should have permanent guide fencing that will not tend to wash away.

d. Structures that allow livestock access to water in a stable pool where the bank or shoreline is protected

by rock or riprap should have a milling area large enough to accommodate the majority of the herd. The surface of the milling area should be chinked with smaller size rock and gravel to assure adequate footing for the livestock.

e. In the longer livestock underpasses, the center portions are quite dark, making passage difficult and slow. This condition should be improved by painting the interior of the structure a light luminous color."

The New Mexico Highway Department has made a film to document stock movement through a 5' span x 6' rise x 200' long concrete box, with and without median opening, using a cow-calf herd of about one hundred head of cows with calves, a yearling herd of about the same size, and the combined herds together.⁷ A narration of the experiment tells of the events and circumstances surrounding the need for such an experiment, and points out details not always evident to the trained or amateur observer. In summary, cattle fresh in from summer pasture, not accustomed to human beings or interstate highways, were herded through two separate structures a total of six times in only half a day, by a typical family ranch operator with two children. This was a good example of a worthwhile and realistic experiment.

Oftentimes, ranchers are convinced these structures are inadequate before they even try to use them. Management innovation becomes an important aspect of utility, and this film shows a rather typical family ranching unit driving the cattle in from winter pasture. Texas is also considering making a film along these lines.

Oregon writes, "A year or so ago, we undertook a study of all cattle undercrossing structures on the State Highway System and interviewed all ranchers

who used the structures. Photographs were also made at each end of the structures. The data was put on our computer and was analyzed. A report is in the process of being written."

PART I

INTRODUCTION

General

The livestock and vehicular underpass has become an expensive item in highway construction. Although it is a very small percentage to total highway costs, it can represent a significant saving, especially if there is an attempt to get maximum efficiency from the underpass. Put in other terms, proper choice of structure size and method of installation will noticeably increase the utility of these structures. "Utility" is commonly defined as the quality or state of being useful.

An estimate of 10 to 25 million dollars presently invested in roadway underpasses (over 6') for private land usage (stock, vehicle and drainage) on the total state system is not an unrealistic figure for our 74,000 miles of interstate, primary, secondary and county rural road systems. While many of these originated as farm to market roads, they can be a constant reminder of land accessibility or non-accessibility to the farm and ranch management.

In 1969 Montana ranked second in the nation in acres of land in farms -- outranked only by Texas. However, in average farm size, Montana ranks fifth -- outranked by Arizona (6,200 acres), Nevada (4,900 acres), Wyoming (4,100 acres), and New Mexico (3,350 acres). Montana has gone from 2,100 acres per unit in 1960 to an average of 2,600 in 1970. The size is increasing and number of units decreasing while the land in production remains fairly constant to slightly increasing. This U.S.D.A., Statistical Reporting Service, and Bureau of Census information was inserted to show the relationship of Montana to similar states,

as well as an indication of agricultural trends.

There is, however, a tendency towards an increase in grazing intensity and decreasing economic returns in the northern great plains region.⁸ Because of relative differences in agriculture and size of units from one state to the other, structure needs will vary from state to state and, understandably, from one landowner to the next.

Pages 5 and 6 are letters concerning vehicular underpasses during the early stages of the interstate program. The observations still pertain, as proven by our research, although a complete analysis was not made at the time of these letters. It shows the concern of officials and action taken during that period.

Purpose

As stated in the original prospectus, Paragraph 4A, Statement of Problem: "A question with which highway designers, right-of-way acquisition personnel and landowners are frequently concerned is whether livestock and machinery underpasses of various designs and lengths can be efficiently used for their intended purpose."

These project objectives were originally defined:

- 1) "To determine whether given classes of livestock will utilize livestock underpasses of various designs and lengths."

The objective of determining utility remains our goal, except that we found in trying to accomplish this objective, the "given classes of livestock" did not vary enough from the

cow-calf Hereford and Angus herds to consider this an influential variable.

2) "To determine optimum machinery underpass design for various types of typical farming operations."

This objective could not be achieved due to the changing equipment sizes, extremely large tilling equipment and combine header widths, as well as home-made innovations. In attempting to achieve this objective, we found that the basic idea is to stress (at the preliminary stages of structure investigation) that all machinery on a farm or ranching unit must be measured for height, width and length. There should be sufficient tolerance, no less than 10%, if at all possible, provided to allow for passage of the machinery with the highest frequency and necessity of usage. It must be recognized that the underpass cannot provide for the largest machinery (in many cases). This is due to excessive machinery size as well as limited economic justification for a particular unit. The metal pipe fabricators, steel companies, and distributors all seem to remain flexible enough to meet the needs of any realistic change in size requirements. Concrete boxes can be built to any specified size up to about 14' x 14'.

Procedure

To begin with, a structure inventory list was prepared by the five district offices from plans and actual field inventory, and sent to the Headquarters Research Unit. A complete statewide inventory of land use structures

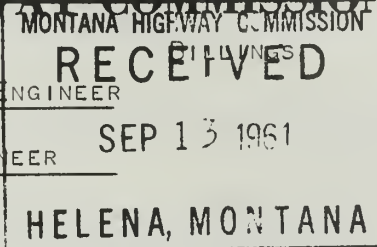
was believed to be too costly, time consuming, and would not better serve the basic purpose of determining utility by livestock and machinery. A total of 450 structures; vehicular, stockpass, combination stockpass and drainage, and drainage structures over six feet in diameter, were located mostly on deeded agricultural lands. One hundred thirty-one were then selected by size of underpass, size of unit, location and intended use, to get a good representative sample of underpasses, whether used as an underpass or not. Random sampling was not possible due to the large number of drainage structures on the original inventory list. To completely eliminate the drainage structures from the sample would affect the sample because of the difference in actual and intended usage; i.e., some drain structures were used for stockpasses. After field screening the 131 underpasses selected, 117 case studies were completed and sent in. However, only 98 of the 117 case studies had sufficient information to draw all areas of analysis from. These were all photographed, measured, inspected and the landowner was interviewed. Where possible, the original appraisals were used for plats and other pertinent information. The actual case study plats are not an engineer's drawing nor intended to display the normal accuracy required for right-of-way purposes. Their primary function is to serve as a picture of the severance situation and to show the size of ranch and remaining acreage on both sides of right-of-way. These case studies are available in a separate report.

INTER-DEPARTMENTAL MEMORANDUM

STATE HIGHWAY COMMISSION OF MONTANA

From PAUL M. JOHNSON, DISTRICT ENGINEER

To LEWIS M. CHITTIM, R/W ENGINEER



Date SEPTEMBER 12, 1961

Subject: EQUIPMENT SIZE
CODE: DM

IN COMPLIANCE WITH YOUR MEMO DATED JULY 31, 1961, THE FOLLOWING IS
SUBMITTED AS PER YOUR REQUEST:

INFORMATION RECEIVED FROM FOUR LOCAL IMPLEMENT DEALERS REVEALS THAT THE
AVERAGE SIZE COMBINE USED IN THIS AREA IS A 16 FOOT PLATFORM AND THE OVERALL
HEIGHT IS APPROXIMATELY $13\frac{1}{2}$ FEET. THIS WOULD REQUIRE AN UNDERPASS NOT LESS
THAN 16' x 18'. TWO FARMERS CONTACTED IN THE REED POINT AREA, NAMELY, ALFRED
NELSON AND MR. GODDARD, EACH HAVE COMBINES WITH THE ABOVE MEASUREMENTS.

ATTACHED ARE SEVERAL PAMPHLETS GIVING DIMENSIONS OF FOUR DIFFERENT MAKES
OF COMBINES WHICH GIVE SPECIFICATIONS OF THE DIFFERENT SIZES OF EACH. IT IS
HOPED THIS WILL BE OF HELP.

OUR AGENTS HAVE REPORTED TO ME THAT THE HEIGHT OF UNDERPASSES AND TUBES
HAVE GIVEN MORE TROUBLE THAN WIDTH IN SETTling PARCELS. IN THE FUTURE, AGENTS
WILL SUBMIT PICTURES OF MACHINERY ON INDIVIDUAL OWNERSHIP BASIS WHICH WILL BE
OF HELP AS TO SPECIFICATIONS OF UNDERPASSES ON INTERSTATE HIGHWAYS.

PMJ/JBB/EL
ENCLS.

Avoid Verbal Instructions

INTER-DEPARTMENTAL MEMORANDUM

STATE HIGHWAY COMMISSION OF MONTANA

From R. B. Dundas, District EngineerTo Lewis M. Chittim, R/W Engineer

RECEIVED

OCT 17 1961

HELENA, MONTANA

Date October 16, 1961Subject: Equipment Size
Code DM

Your memorandum of July 31st was transmitted to the Right of Way Department and we quote here following comments therefrom: Right of Way-Agent Ford, reports:

"Relative to the adequacy of machinery and stock passes a number of passes were observed and it appears the size of the pass required will vary considerably with the type of farming or ranching, type of livestock using the pass, length of pass and time of year that pass will be used. Livestock having free access to pass will gradually become accustomed to them especially in summer when they may go into a pass for shade. Farm livestock such as dairy cows used to going into barns will go through smaller passes than range cattle. A pass through a narrow fill where light is ample does not require as large a type as a pass through the Interstate. Concrete tubes (elliptical) are preferred to the metal tubes and a square concrete walled structure is preferable to either type of tube. In my examination of tubes and passes in place one small pass estimated 6 ft. in height on the White Sulphur Springs-Townsend road was of no value as stock would not go through it although not of great length and light showed through it while a 132" (11 ft.) pass on the Victor Chemical Road near the Railroad overpass and having a curve and no light showing through showed evidence of use by range cattle. Stock passes on the Big Timber south 10' x 10' showed evidence of free use by livestock and would be large enough to drive cattle through. Ranchers with whom this problem has been discussed state that a pass of less than 84" (7ft.) is of little value and height of 7'7" is minimum to permit a horse as they have a tendency to strike their heads on a lower pass. In checking width and height of machinery being used in this area the farmers growing grain and using combines would require machinery passes of not less than 20 foot width and up to 24' width for larger combines with a height clearance of not less than 12½ feet. Very few machines used in grain or hay production were found that would require less than a 14' width and 12' height."

Right of Way- Agent Hoiekvam, reports:

" Relating to cattle passes under Interstate Roads, I have not had any contact with owner relating to same, but on Primary and Secondary Roads the owners who were contacted desire a cattle pass of a minimum height of 7 feet. The 84" round concrete stock pass is from the statements from the rancher are more desirable than the metal ones."

If we collect any further information on subject we will forward to you for your information and files.

RBD:JVK:cb



Avoid Verbal Instructions

PART II

CASE STUDY FORMAT - DESCRIPTION

1) CASE STUDY NUMBER, TYPE OF ACCESS, AND DATE OF INSPECTION

The case studies were numbered as they were received from the districts. The time of inspection, between July and October, was important. We wanted to investigate these structures during a period of most frequent usage to find the predominant trouble spots. All cattle had not been moved in from summer pasture when the last case study was sent in. There was some follow-up investigation during winter on the snow troubled pipes. Sample Case Study No. 55, pg. 15 is a good example of a fairly typical underpass.

The "type of access" was an important part of the study so as to determine adequacy by type of highway and access control. Refer to chart on page 21. Controlled access (four-lane) and controlled access with temporary rights of access (two-lane) pertains to interstate highways. Non-controlled access pertains to primary and secondary highways.

2) PRINCIPAL SEVERANCE SITUATIONS

The primary reference in each case study for the livestock and vehicular underpasses will be the severance situation. This is singularly the most direct means of property comparison for highway influence. This describes the relationship of the remainders on each side of the highway connected by the underpass, and indicates the most significant management problem resulting from the severance. As used in this study, the ranch is primarily a cattle producer and the farm is primarily a grain producer.

There are eight selected categories. These have been condensed from

the many varying situations to the most common denominator. To further reduce these categories would substantially alter the objective.

A. The headquarters and main unit are separated from winter pastures.

Here we have varying problems created by limiting access points across a once-open winter range, excepting in cases of extra widening and reconstruction of existing roadways. The rancher cannot readily see all of his cattle and sometimes has difficulty moving them to shelter and water during snowstorms as well as moving feed and water to the cattle. This is quite a restrictive severance situation.

A-1. The headquarters and main unit are separated from the winter pastures and stockwater.

This would be similar to situation 'A', however, some or all of the stockwater is on the opposite side of the roadway from the main grazing and headquarters area. There are varying situations and management problems resulting from isolating stock from water, but for purposes of this study, they will all be cataloged under 'A-1'. This will most likely occur in a valley bottom or single pasture.

A-2. The headquarters and winter pastures are separated from the main unit.

This is a slight physical location variation from category 'A', but substantially different from a management viewpoint. During the winter and calving season, the herd is usually within easy access of the headquarters buildings for feeding, watering and calving. Access points are not crucial to this phase of management. The problem arises when desiring to use the remaining pasture early in spring or late in fall, as well as during large herd drives to summer grazing. The cross-

ing access is limited to one or few points for the average size cattle or farming operation. This is not as severe a severance situation as 'A'.

- B. The headquarters and main unit are separated from the summer grazing pastures. This situation differs slightly from 'A'. Here, the headquarters buildings and most of the land remain on one side and the right-of-way borders the irrigated and grazing lowlands, trying not to take the more productive lands. The rancher is usually confronted with herding cattle to summer pasture through the underpass. The summer pastures are separated from the main unit by the highway and crossing access points are usually limited to one or few places. Fifty-two per cent were judged adequate in this category. This is the least damaging severance situation. As Chart #5 on page 28 shows, it is also the most frequent severance situation.
- C. Separated haylands. This occurs when the right-of-way severs an irrigated or sub-irrigated hay meadow. Management problems are usually involved with proper winter feeding and machinery movement from one side to the other. This does not necessarily adjoin the home ranch as in category 'A'.
- C-1. Separated croplands. This is similar to 'C', with the variation in crop. This is usually wheat, however, other small grains might also be involved. Larger machinery is utilized to harvest the crops. Plows, harrows, and combines are generally larger and require structures of greater width and height than for planting and harvesting hay or moving stock. In general, the grain operation will require a larger underpass than a cattle operation. Often a county road separation will serve the purpose.

D. Community underpass; separated pastures and croplands. Several users utilize a single underpass. There are usually easements and gates, allowing access to each ownership for cattle and vehicular traffic.

D-1. Access to forest permit. This will occur on public lands (Bureau of Land Management, Forest Service) where several users may have need to cross the right-of-way to utilize their grazing permits. The structures are usually intended for driving stock.

E. Headquarters landlocked. This happens when the right-of-way severs all access to a farmstead or ranch headquarters. An underpass is sometimes the only access where a frontage road is not feasible. This is, understandably, not a desirable situation.

3) TYPE OF OPERATION

Each case study shows the type of farm or ranch operation and its size in number of head or animal units or farm acreage. Ninety-eight structures were classified as to the type of ranch or farm operation they served; this resulted in the following breakdown:

70 - Self-contained and mostly contiguous cow-calf Hereford or Angus ranch units; 38, or 54%, were judged adequate;

4 - Cow-calf and sheep;

8 - Mixed cows, calves kept to yearlings for feeders;

4 - Community-use underpasses;

4 - Dairy;

4 - Cow-calf and farming;

2 - Stockers or feeders;

1 - Farm -- most farms on controlled access interstate have access to county road separations; on primaries, over the surface at-grade approaches are usually available;

1 - Mining operation.

98 - TOTAL

The most numerous breed in this study was the Hereford. They are noted for their high plains endurance, beef content, and are reasonably manageable. Angus, although they have a higher resistance to disease, were felt to be a more stubborn, hard-to-manage critter, and frequently need a lead cow or bull to get through the underpass. Experts say there is as much difference in cattle of one breed as between two separate breeds, however. There were no conclusions reached as to the breed most adaptable to these underpass situations.

The four dairy cattle herds were all Holstein; they are the largest milk producers. One operator mentioned he only runs the bulls, dry cows and replacement stock on the severed portion and has had good luck using 4-H heifers to lead stubborn cows through his 108" x 276' structure. One observation was that on sunny days the cattle refused to go beyond the shaft of light shining down into the pipe from the median drain, but experienced no trouble on cloudy days. Two of the four structures on dairy units were judged completely adequate: the 108" x 276' pipe and a 96" x 128' pipe. One "A" type, formerly unused, will be utilized by new owner. The fourth was a 20's x 14'r concrete box adequate for stock but ices up in wintertime and poses vehicular problems.

4) LOCATION

A geographic description (distance to nearest town), section, township and range, county as well as project number, and stationing, was used to pinpoint the locations.

5) STRUCTURE TYPE

All structures were listed showing designed dimensions whether round,

squash, arch or box, as well as the use of the structure (stockpass, stockpass-drainage, vehicular or combination). One end of each structure was measured to compare dimensions after installation with design dimensions. The amount of cover over the pipe was also measured. Seventy-five per cent of the structures were found to be within the 4% measurement tolerance required by the Standard Drawings design book. These had an average fill of 5' to the top of roadway and 61% were judged adequate for usage as livestock or vehicular underpasses. Twenty-five per cent were found to be squashed out of round or damaged beyond the designed tolerance limits. These had an average fill of 15' to the top of roadway, and 29% were judged adequate. The average variation was 7.0% off design measurements, median was 6.5% with a range of 6% to 14%. All structural steel and plate pipe will be referred to as C.M.P., "corrugated metal pipe", for purposes of this study.

6) SPECIFIC PROBLEMS

Each problem was specifically outlined in the case study. Various experiences came to light which normally might not receive consideration. Some unusual situations were: an injury to a person on horseback in a metal pipe; cattle bunched up and near suffocation in a small stockpass during a snowstorm; cattle slipped on an iced-up structure and were not able to get up, some were bruised on the protruding bolts from slipping and falling. Cattle would sometimes fight trying to turn around to go back through the stockpass. Vehicles would get stuck in the structures in mud, ice or snow. Highway Commission snowplows sometimes plow the entrances full (over the side, into the entrance) on all classes of highways. One large arch pipe has caved in twice, resulting in excessive maintenance costs. Many pipes had to be paved after construction

when it was discovered cattle were hesitant to go through them on the metal surfaces. The above examples are not the average but extremes of management and maintenance problems connected with a livestock and vehicular underpass.

7) ADEQUACY

Each structure had to be judged adequate by both the landowner and investigator to receive an adequate rating. If there were varying opinions on utility, they would fall into one of several categories:

- (a) Adequate - high utility, and satisfies the user's needs. Fifty-two per cent of all structures fell into this category.
- (b) Conditionally Adequate - moderate usage, fair utility, but is limited to the type of machinery that can be taken through; cattle will cross under certain conditions. For example: size, light and surfacing are conditions which affect utility. Fifteen per cent fell into this category. Because of extraneous circumstances innovations were tried to get cattle through the stockpass, such as use of holding pens; however, cattle will not use the pipe if it is silted in deeply. (Higher utility than "Seasonally Adequate").
- (c) Seasonally Adequate - usable only during favorable weather months. Usually found in high elevations, heavy snowfall areas, drifting locations, or in drained areas having a high frequency of drainage runoff which creates boggy situations for stock. Eight per cent fall into this category. This does not include those intended only for summer usage which may or may not have been judged adequate. (Higher utility than "Barely Adequate").
- (d) Barely Adequate - very low utility. Six per cent of all structures fell into this category. For example: the pipe might have been undersized for the type of ranching unit.
- (e) Super Adequate - structures installed that were larger than necessary for the operation. Judgment

was made by investigator. Only 2 out of 98, or 2%, fell into this category.

- (f) Inadequate - complete negative attitude of the landowner regarding the structure, and in most cases, the investigator as well. Eleven per cent of all structures fell into this category.
- (g) Unused - no use for various reasons: resale of portions, 1%; spite, 1%; change of type of operation, 3%; landowner feels it is inadequate, 1% -- for a total of 6%.

8) REMARKS

This final portion of the narrative was intended to bring to light any results, recommendations, conclusions, opinions, or judgments that would not fit anywhere else in the report. It most generally included additional details and comments upon the case situation.

PHOTO PAGE

This contains photographs of each entrance, and a photo looking away from both entrances. In special cases, additional pictures were taken to assist in visualizing the complete situation. It is well to note detail as to trail patterns, entrance erosion, wing fencing, topography or any other visible evidence relating to physical usage.

PLAT PAGE

There were 73 plats available of the case studies investigated. They are intended to show the principal severance situation, amount of land severance, general location of farmstead, water, roads and other pertinent physical features, where possible.

LIVESTOCK AND VEHICULAR UNDERPASSES

CASE STUDY NO. 55 - Controlled Access With DATE OF INSPECTION: September, 1970
Temporary Right of Access

PRINCIPAL SEVERANCE SITUATION: Separation of grazing pastures; about 1,107 acres remain north and 1,002 acres remain south.

TYPE OF OPERATION: Cow-calf -- runs 200 head of cows. He moves them from south side late in fall to the north side for wintering. He also runs 300 ewes on north side.

LOCATION: About 10 miles east of Glendive, located in Section 5, Township 15 North, Range 57 East, M.P.M., Dawson County. Station 697+15 on Project 1 94-6 (6).

STRUCTURE TYPE: 96" diameter x 92' long, C.M.P., combination stockpass-drainage, with about 1½' to 2' of cover.

SPECIFIC PROBLEMS: There is very little slope, which does not allow drainage to flush the manure out of the pipe (see top photo). The pipe has settled in the center so there is a low spot. Pipe is misshapen to 7'6" span x 9' rise from the original 8' diameter, which possibly indicates side compression. It is located on a down-grade roadway with very little cover, which may affect original designed measurements depending upon durability of roadway; or, it may be used as a shelter by cattle in summertime, accumulating manure from the numbers of cattle, and changing the shape of the pipe slightly because of weight distribution. Snow occasionally blows both ends of the pipe full. Rather than fight this, the owner runs stock west about one mile, under an Interstate bridge, and back.

ADEQUACY: The owner feels the pipe should be larger and perhaps have been a squash pipe for use with a pickup. Horses move through the pipe easily but he has never tried to move his sheep through. He has had to build new corrals on the south side at a cost of \$500.00. He is also planning to develop springs or a well on the south side. This structure is considered barely adequate.

REMARKS: This appears to be a heavily used stock structure. Manure builds up along with drainage silt, and has to be cleaned out periodically. There are not practical machines to do this for an 8' pipe, so it is all done by hand. If the user must also clear this of snow to use it, it makes the underpass adequate only because of the maintenance by the user. The owner had a 60" pipe under the old highway, so his cattle and horses were used to using a stockpass, although somewhat shorter in length.

I 94-6 (6)
GLENDIVE-EAST

96' x 92' long, C.M.P.
Stockpass-Drainage



NORTH ENTRANCE, looking towards
Southeast; Notice fill material
cleaned out of pipe



NORTH ENTRANCE: Notice pipe is mis-
shapen



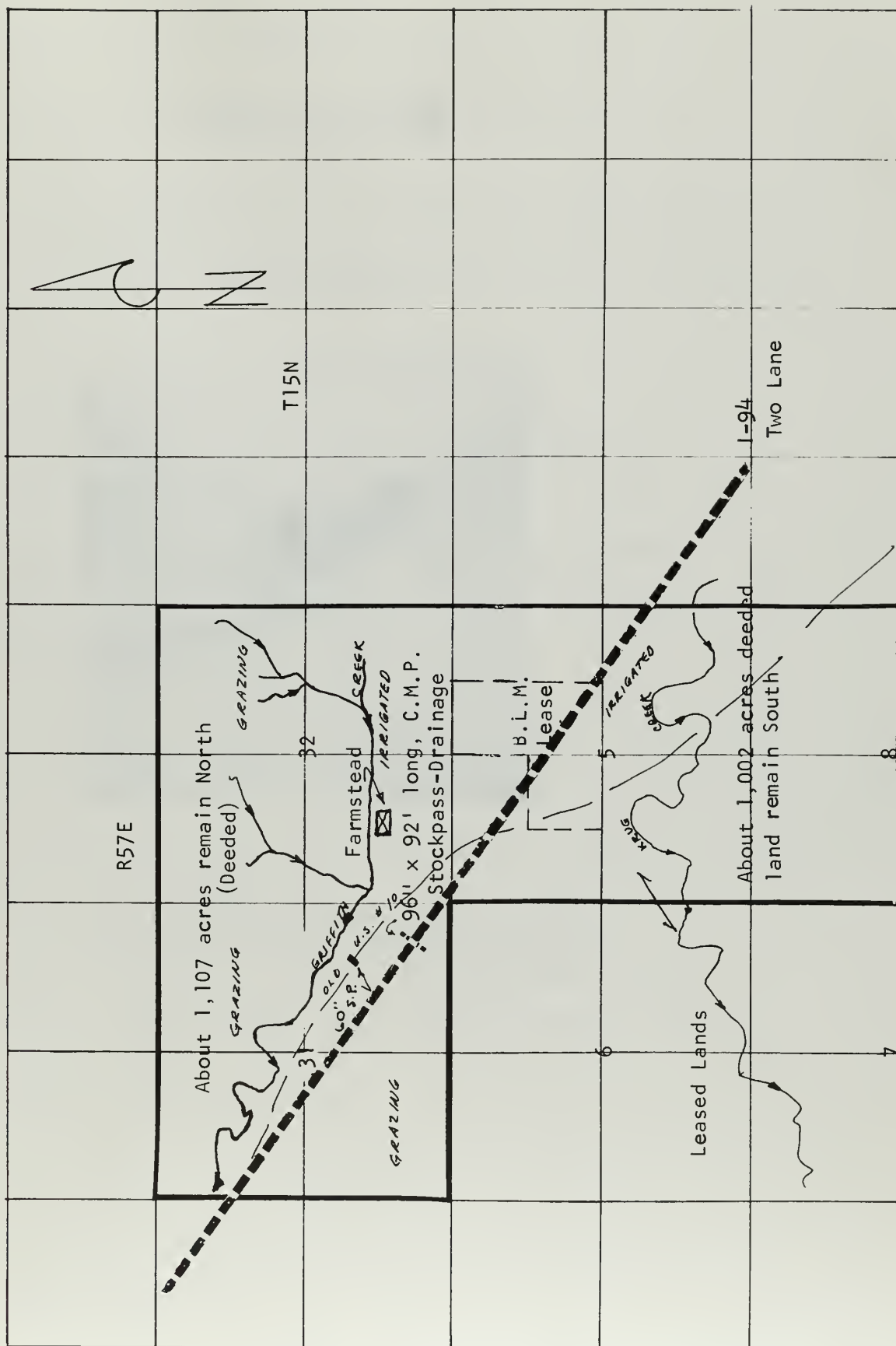
SOUTH ENTRANCE



Looking Northwest from NORTH ENTRANCE
Notice pipe under old highway #10



Looking South from SOUTH ENTRANCE
Upward sloping hills

OWNERSHIP PLATSCALE 1"=1/2 mile Principal Severance Situation Separation of grazing pasturesDATE 9/70 CASE STUDY NO. 55 STRUCTURE AGE 6 yrs. PROJECT NO. I 94-6 (6)

Case Study #55



North Entrance; photo taken January, 1971.
Livestock have been taking shelter during
snowstorms.

PART III

STATISTICAL SUMMARIES

The use of frequency diagrams and histograms most simply depict the characteristics of structure features. These consider utility as a function of several variables:

- 1) Highway system (interstate, primary, secondary);
- 2) Type of underpass (arch, round or box), actual and planned use (stockpass, vehicular, drainage, or some combination);
- 3) Physical location (top, flat, bottom, side), and actual use compared to planned use as regards drainage;
- 4) Length of underpass;
- 5) Severance situation.

The objective of the frequency diagrams is to identify the most pre-dominant factors affecting the utility of structures. Other variables not charted with reference to adequacy but described in the case study format or in this chapter, with regard to possible effect, are:

- 1) Type of operation -- yearling, cow-calf, farm or mixed;
- 2) Type of structure, actual and designed measurements, and amount of cover on pipe;
- 3) Specific drainage situations.

Other variables too vague to be considered are:

- 1) Efficiency of management;
- 2) Non-contiguous lands;

- 3) Number of natural or man-made barriers also directing stock movement (streams, railroads, existing rights-of-way);
- 4) Cattle breed -- other than dairy, experts say there can be as much difference in temperament among cattle of one breed as among two separate breeds;
- 5) Land productivity on severed portions.

This study did not warrant gathering a large enough sample of structures to test hypothesis by means of the various statistical measurements or to test significance of one variable upon the others through simple and multiple regression. The universe population would only consist of 1,000 underpasses, at most, including 50% drainage structures all over 6' in diameter.

The frequency charts shown on pages 21-25 are intended to show several measurements statistically. The number of observations were taken from 98 completed case studies. Any information or conclusions not supported by the Underpass Summary Charts have basis in fact and can be verified by information in our files.

CHART #1

NUMBER OF STRUCTURES ADEQUATE

BY HIGHWAY SYSTEM:

INTERSTATE	Two & four lane, controlled access 55% Adequate				
	19%	12%	4%	10%	
	C.A.	S.A.	B.A.	Inad.	
	0	27	36	42	44
	Number of structures; Average length = 150 feet				
PRIMARY	Two lane, non-controlled access 53% Adequate				
	16%	8%	11%	11%	6%
	C.A.	B.A.	Inad.	U.	
	0	10	19	25	26
	Number of structures; Average length = 106 feet				
SECONDARY	Two lane, non-controlled access 69% Adequate				
	7.7%	7.7%	7.7%	7.7%	
	C.A.	S.A.	I.	U.	
	0	9	10	11	12
	Number of structures; Average length = 84 feet				

Chart No. 1 breaks the highway system into three parts and classifies the structures as to their degree of utility or adequacy. Adequate (A), Conditionally Adequate (C.A.), Seasonally Adequate (S.A.), Barely Adequate (B.A.), Inadequate (I), or Unused (U). There are two out of ninety-eight listed as Super-Adequate, but for purposes of this analysis, the logical place to classify them would be within the Adequate category. There is no noticeable difference between the controlled access Interstate highway and the non-controlled access Primary highway as to the percentage of adequacy. However, the secondary road shows the highest amount of acceptable underpasses. Although a small number constitutes this sample (13), it could mean that lower traffic count and narrower right-of-way width results in greater convenience of surface crossings, thus reducing the dependence on underpasses. This helps to make management problems less difficult.

CHART #2

NUMBER OF STRUCTURES ADEQUATE

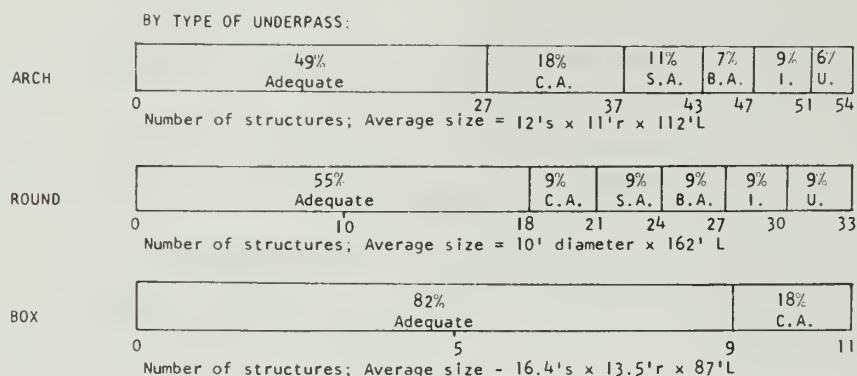


Chart No. 2 is intended to show the percentage adequate for the three main structure types. Forty-nine per cent of the arch pipes are fully adequate compared to fifty-five per cent of the round pipes and eighty-two per cent of the boxes. Although the concrete box bridge-type structure comprises a much smaller sample, there does appear to be a statistical advantage of these over the others. The obvious reason is the large size of the boxes (of course, at added expense) ranging in size from a 14' span x 10' rise to a 20' span x 14' rise, with an average size of 16'5" span x 13'6" rise x 87' long. The average round pipe is 10' in diameter x 162' long and ranges from 72" to 180" in diameter. The arch pipe averages 12' span x 11' rise x 112' long and ranges from 5'10" span x 6'6" rise to 20'5" span x 13'0" rise. The higher utility of the concrete box is due to the larger size and proper location. Utility of the arch and round pipe is largely dependent on drainage situations. Extreme lengths hamper the usability of the structure due to the amount of light, type of use and type of cattle using the underpass.

The average length of round pipe, at 162' long compared to 112' for the arch pipe, indicates the larger number of round pipe located in drainage areas (19 out of 33 have a bottom location requiring more fill and hence a longer pipe; 13.5' average fill for circular pipes as compared to 4.5' average fill for arch pipes); 23 out of the 33 round pipes are designed to carry drainage, compared to 14 out of the 54 arch pipe (70% as compared to 26%). Sixteen out of the fifty-four arch pipes have a bottom location, although thirty-five of the fifty-four (continued on next page)

also carry some drainage not designed for the structure. This information (35 of 54 arch structures) cannot be verified by the chart because these factors were all listed as mentioned by the landowner. The thirty-five structures were taken from the case studies. The limited drainage in these was substantiated by the investigator and photographs. This helps to explain the somewhat lesser adequacy of the arch pipe as compared to round. The round pipes were designed to carry drainage but the arch were not and hence developed more management problems. Those arch pipes listed as conditionally adequate usually were not wide enough for all desired vehicles, or large herds.

Field interviews with the ranchers strongly favor the arch pipe as compared to round, even though a round pipe might be judged adequate by the landowner. There is more usable area in the arch pipe, cattle do not slip and fall as easily, and the arch pipes permit a greater variety of vehicle usage and width for stock usage for a comparable pipe periphery.

Because structural plate steel is primarily sold by the pound, the initial cost might favor the arch pipe. Installation costs vary with the specifications for each structure. The amount of plant mix required will vary with the size of the pipe, depth desired and travel surface width desired. Entrance stabilization costs will vary with the amount of usage and drainage.

CHART #3

NUMBER OF STRUCTURES ADEQUATE

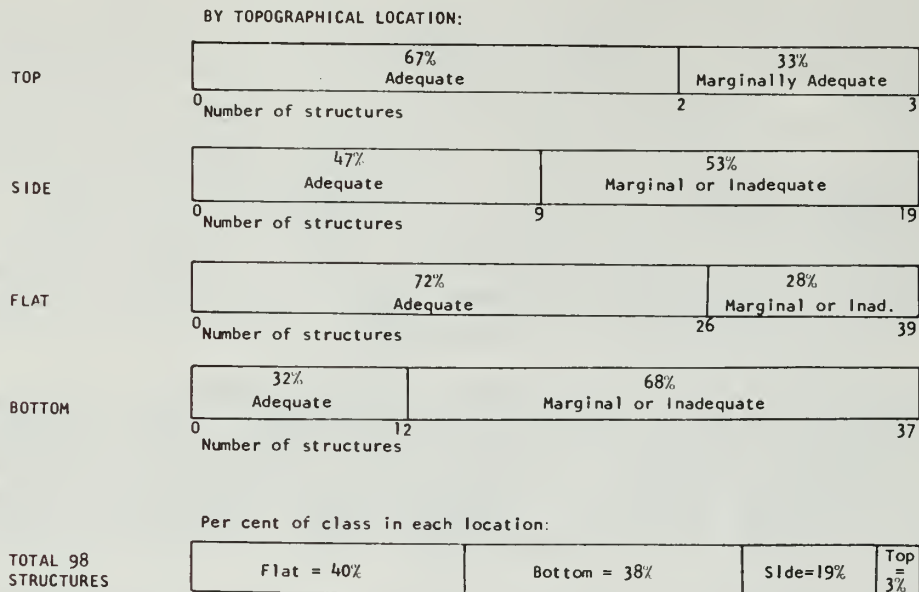


Chart No. 3 shows the number of structures in each of four topographical locations. By far the most adequate locational category, with respect to the sample size, is the Flat location with 72% adequate, followed by 67% adequate on the Top location, 47% adequate Side location, and 32% adequate Bottom location. The reason for the lower ratings on bottom locations usually has to do with drainage, excessive length, and access problems. Washout, soft areas, snow drifting, are all contributing problems in a low spot. There are exceptions where it was found an underpass located in a gully was sheltered during the wintertime, but experienced bog and drainage during spring runoff. These are the less costly locations with respect to grading costs.

The marginal or inadequate portion of the chart is intended to describe the remaining categories of adequacy (Conditionally, Seasonally and Barely Adequate, Inadequate and Unused). Although Conditionally Adequate has a fairly high rating with respect to actual utility, this analysis is more appropriate without regarding conditional use as adequate.

The bottom graph shows the distribution of the four physical locations for all 98 structures. Again, Flat and Bottom locations are most predominant due, in part, to the lesser grading required in these locations. Other factors are natural stock trails, stock-to-water trails, and combination drainage structures which usually are found in a recessed area.

CHART #4

FREQUENCY DISTRIBUTION OF STRUCTURE LENGTHS

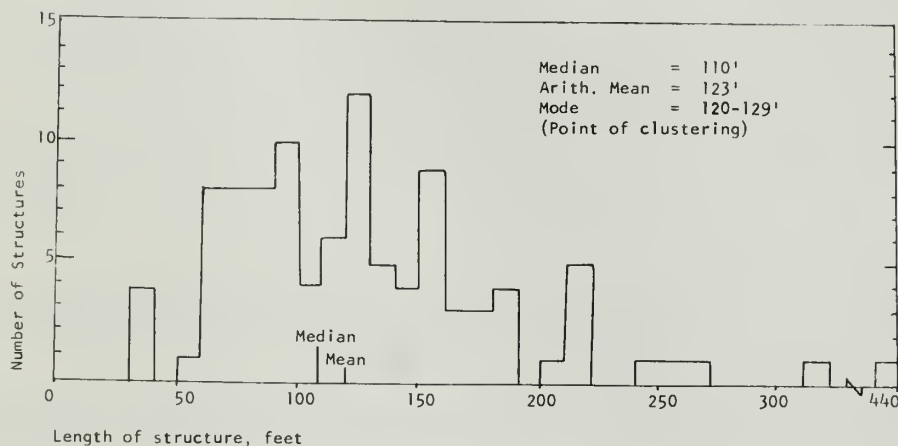


Chart No. 4 merely shows a frequency distribution, in histogram form, by lengths; all structures in the sample. The median is 110' in length, arithmetic mean is 123' (13' difference), and range of 44' to 439' with a midpoint of 241'. The median and arithmetic mean are close enough together to give us a fairly good figure for a statewide "average length" of structures. For example, the average "round" pipe was 10' in diameter x 162' long, with a median of 150' long (12' difference).

The smaller "A" and "B" arch type pipes, as well as the eleven concrete box structures, are all under 160' in length. Thus, our longer structures are (1) some of the larger arch pipes, and (2) some of the circular pipes above 6' in diameter which have been installed for stock and/or vehicular usage.

The fifth chart is designed to show which severance situation is most common. By far the most common situation was "B", that the headquarters and main unit are separated from the summer pastures; in 49.5% of the cases. This is also not as severe a severance damage as the following:

The order was such: (Chart No. 5)

- 2) A-1 - 17.2% -- The headquarters and main unit are separated from winter pastures and stock-water. (Restrictive severance)
- 3) A-2 - 9.7% -- The headquarters and winter pastures are separated from the main unit. (Restrictive severance)
- 4) A - 8.6% -- The headquarters and main unit are separated from winter pastures, new location. (Restrictive severance)
- 5) C - 4.3% -- Separated haylands. (May or may not be restrictive)
- 6) C-1 - 4.3% -- Separated croplands. (May or may not be restrictive)
- 7) D - 3.2% -- Community underpass; separated pastures and croplands. (Not a severe severance situation if handled properly)
- 8) E - 2.1% -- Headquarters landlocked. (Restrictive severance)
- 9) D-1 - 1.1% -- Access to forest permit. (Not severe)

In the most common severance situation - "B", 22 of the 45, which is 49% of the structures, were judged adequate. Seven were judged inadequate, or 15%; seven were unused, or 15%; four were barely adequate, or 9%; two were conditionally adequate, or 4%; and four were seasonally adequate, or 9%. One significant thing is that adequacy and utility does not seem to be dependent on the severance situation. The distribution of adequacy measurements in the "B" severance situations is not too different from the distribution for all structures, (page 13), except there were fewer in the "Conditionally Adequate" category, and more in the "Unused" category.

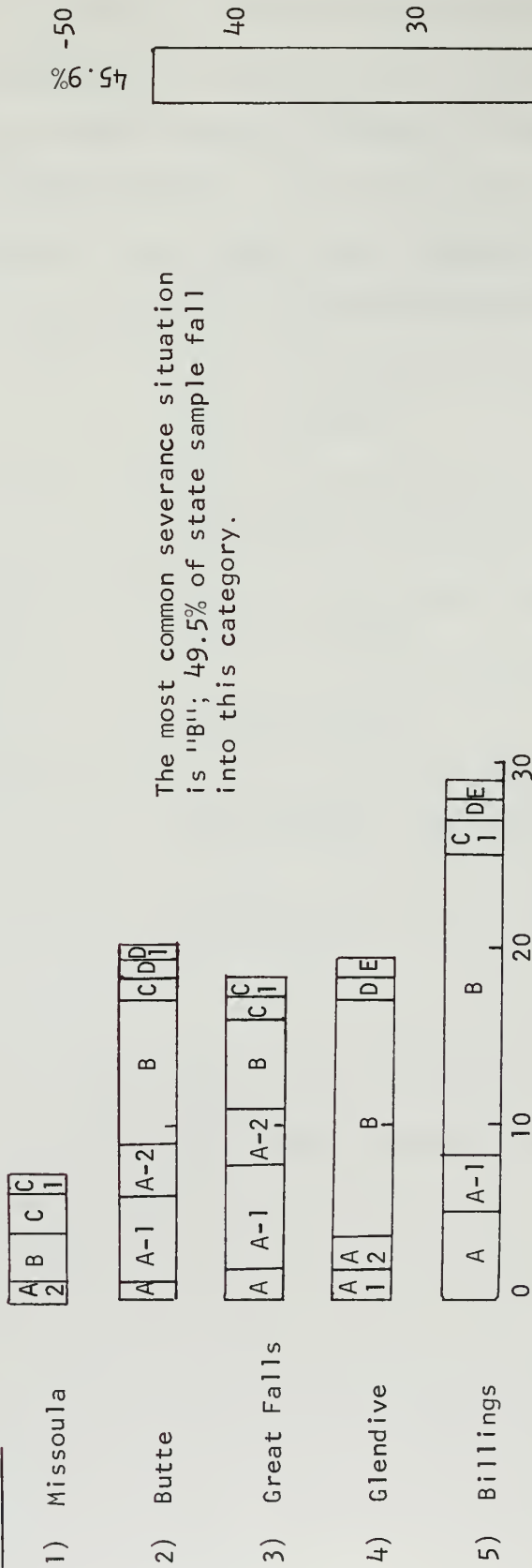
Billings and Glendive appear to have a majority of "B" severance situations, with Butte, Great Falls and Missoula having less than 50%. There were several ranches that fell into more than one category of severance situation; however, to remain as consistent as possible, only one category was chosen to statistically represent each ranch or farm unit. The "B" situation is the least damaging to the ranch unit. There were a sufficient number of observations in this category to measure the adequacy, and compare it to the whole sample.

F R E Q U E N C Y D I A G R A M S

98 Structures

Statewide Samples

CHART #5

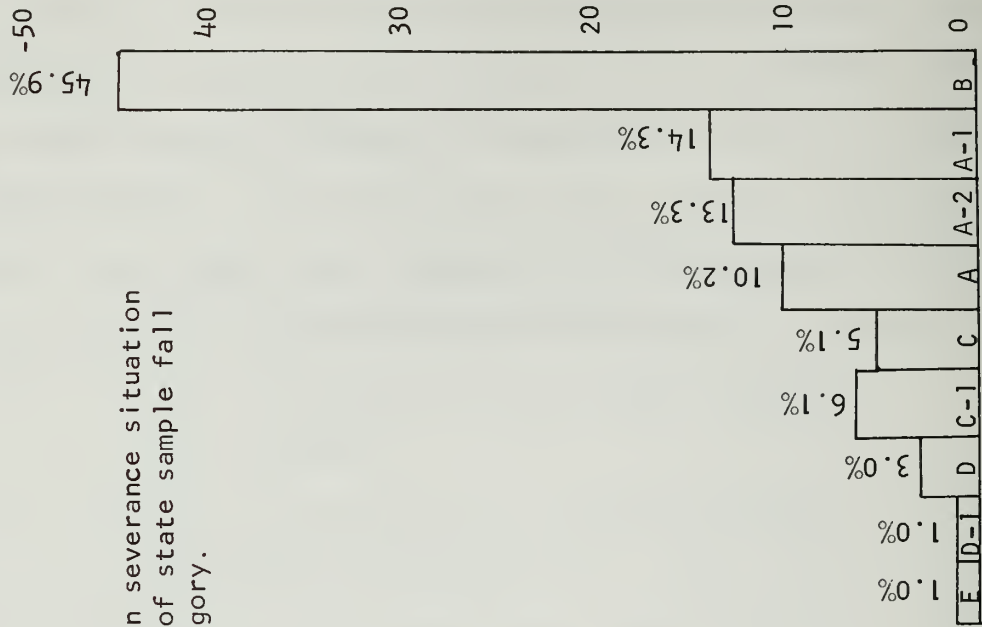


The most common severance situation is "B"; 49.5% of state sample fall into this category.

NUMBER OF SEVERANCE SITUATIONS, BY DISTRICT

- A. Headquarters and main unit are separated from winter pastures; new location.
- A-1. Headquarters and main unit are separated from winter pastures and stockwater.
- A-2. Headquarters and winter pastures separated from main unit.
- B. Headquarters and main unit are separated from the summer grazing pastures.
- C. Separated haylands.
- C-1. Separated croplands.
- D. Community underpass.
- D-1. Access to forest permit.
- E. Headquarters landlocked.

PRINCIPAL SEVERANCE SITUATIONS 98 Structures



UNDERPASS SUMMARY - Narrative

The underpass summary pages show the underpass and its intended or designed use; the adequacy for livestock and/or vehicular use; factors affecting adequacy; severance situation; topographic location; and a column for remarks peculiar to the underpass.

This contains some of the data the statistical analysis is based upon. There does appear to be sufficient evidence to warrant consideration of separate structures for underpass and drainage use. Thirty per cent of the structures contained enough drainage to limit the use of the structure. Of these 28 structures, 12 were designed as combination drainage and underpass structures, but do not function properly for underpass use. The remaining 16 were not designed for combination underpass and drainage use, but had drainage problems severe enough to limit the usage. It could be concluded that, regardless of intended use, separate structures for drainage and underpass use are preferable. Those landowners and maintenance people who have wrestled an old fresno or one-horse slip along a corrugated metal pipe bottom to clean out a small combination-drainage stockpass probably would have, understandably, a certain amount of antagonistic feelings about these situations. Those underpasses large enough to accommodate a front-end loader do not have this specific problem; however, there are some unmanageable drainage collection situations that render the large underpass too boggy to use and impossible to clean.

This list also shows the snow and ice conditions affecting usage. Eighteen per cent had serious snow problems and 9% serious ice problems. The total reflecting problematic snow conditions is 35 (36%); however, 14 of these are considered adequate structures, whether used seasonally or year around. Only 17 of the 98 structures had no problems to speak of. Whatever minor items affected

these structures during usage, nothing was serious enough to warrant mentioning during the interview. The more positive features of these particular structures were favorable locations with respect to drainage and weather, proper design and subsequent construction installation, and a size acceptable to the ranch owner.

The discussion on utility (page 35) was not empirically conclusive as to the size (area opening) to length relationship. We do know that the adequate circular stockpass averages 130' in length, and any circular stockpass not considered adequate averages 154' in length. There tends to be some indication that extreme lengths are not desirable in any size; particularly the smaller structures, 9' in diameter or less. We cannot say definitely that length is a deterrent factor. Landowner criticism and experience with the small, long underpasses would probably justify fully exploring all alternatives before installing one. Even then, it would most likely be least embarrassing and most practical to consider payment of damages in lieu of installing an underpass that has less than half a chance of being adequate for a stockpass. (Compounded by a problem of excessive length, the underpass has somewhat less than half a chance of being useful, if judgment is a valid measurement of such). We also know that light and sound have a certain negative affect in longer underpasses, but not to what extent. There is also a natural hesitancy by wild range cattle to enter the structure. Be there any doubts on this, the herding of range cattle through a barn (in one door and out the other) is a proper comparison. The results are similar to the stockpass as to herd reaction. If there is any doubt about minimum width required for vehicle movement, driving a car through any garage door less than eight feet in width should eliminate those doubts. There is just enough clearance to pass through without scraping a car of average width.

CASE STUDY NUMBER	UNDERPASS IDENTIFICATION BY SIZE & LENGTH	INTENDED USE			ADEQUACY FOR UNDERPASS USE				FACTORS AFFECTING ADEQUACY MENTIONED BY LANDOWNER X = Severe Enough to Limit Use; 0 = Not Serious Enough														REMARKS
		LIVESTOCK	VEHICULAR	ORAINAGE	AOEQUATE	LESS THAN ADEQUATE	INADEQUATE	UNUSEO	SOME FORM OF DRAINAGE	SNOW	ICE	INADEQUATE SURFACING	UNDERSIZED	LOCATION ON PROPERTY	LARGE HERD SIZE	OWNER'S ATTITUDE	NONE TO SPEAK OF	SEVERANCE SITUATION	TOPOGRAPHIC LOCATION				
									STOCKPASS	SIZE	ARCH	PIPE											
29	5'10''s x 6'6'' r x 76' L	X			X							0						X	FL				
60	Same; ''A'' x 78'L	X						X	X	0								X	FL	New owner will use			
61	Same; ''A'' x 72'L	X			X											0	A-2	FL					
76	Same; ''A'' x 60'L	X				X				X	X							A-1	FL				
77	Same; ''A'' x 76'L	X		X			X		X	X								A-1	FL	Excessive Snow			
78	Same; ''A'' x 60'L	X			X											0	C	FL					
79	Same; ''A'' x 60'L	X			X					0								A-1	FL				
80	Same; ''A'' x 60'L	X				X				X								A-1	FL				
47	Same; ''A'' x 78'L	X			X										0			B	SD				
49	Same; ''A'' x 92'L	X			X											0		B	SD				
51	Same;''A'' x 150'L	X			X				0	0	0							B	BT				
52	Same;''A'' x 160'L	X		X	X				0	0								A-1	BT				
100	Same; ''A'' x 86'L	X					X									X		X	BT	Two ownerships involved			
65	5'10''s x 7'7''r x 54' L	X					X		X									B	SD	Mud Accumulation			
66	Same; ''B'' x 87'L	X			X				0									B	BT				
67-68	2 - ''B'' x 114'L	X						X	X									B	BT	Change in High-est & Best Use			
70	Same; ''B'' x 81'L	X			X											0	C	FL					
39	Same; ''B'' x 80'L	X				X									X			B	FL				
25	Same; ''B'' x 96'L	X			X											0	A-2	SD					
26	Same; ''B'' x 98'L	X				X				0						X		A	SD				
27	Same; ''B'' x 88'L	X			X				0									A-1	FL				
48	Same; ''B'' x 80'L	X			X				0	0								A-2	BT				
81	Same; ''B'' x 96'L	X						X								X		B	SD				
101	Same; ''B'' x 76'L	X		X				X	X									C-1	BT	Small amount of pasture not used			
102	Same; ''B'' x 76'L	X						X						X				A	FL	Moves stock across highway			
103	Same; ''B'' x 92'L	X		X		X				X								B	BT				
2	6'11''s x 8'6''r x 150' L	X		X		X			X									D-1	SD				
6	Same x 262'L	X	X		X							0						B	FL				
82	Same x 120'L	X	X			X			X	X	X		X					A, A-1	SD				
40	9'6''s x 5'7''r x 60'L	X		X	X							0						A-2	TP				
30	SUBTOTAL	30	2	6	15	7	3	5	X-7 0-5	5 6	2 1		1 1	1 1	1 1	3	5						

CASE STUDY NUMBER	UNDERPASS IDENTIFICATION BY SIZE & LENGTH	INTENDED USE			ADEQUACY FOR UNDERPASS USE				FACTORS AFFECTING ADEQUACY MENTIONED BY LANDOWNER X = Severe Enough to Limit Use; 0 = Not Serious Enough													REMARKS
		LIVESTOCK	VEHICULAR	DRAINAGE	ADEQUATE	LESS THAN ADEQUATE	INADEQUATE	UNUSED	SOME FORM OF DRAINAGE	SNOW	ICE	INADEQUATE SURFACING	UNDERSIZED	LOCATION ON PROPERTY	LARGE HERD SIZE	OWNER'S ATTITUDE	NONE TO SPEAK OF	SEVERANCE SITUATION	TOPOGRAPHIC LOCATION			
								VEHICULAR	SIZE	ARCH	PIPE											
5	10'10 $\frac{1}{2}$ "s x 9'11"r x 206'L	X	X			X			X	X								B	SD			
28	11'5"s x 7'3"r x 82'L Squash	X		X	X				0									B	FL			
104	Same x 110' L	X			X				0									B	SD			
24	12'8"s x 8'7"r x 90'L Squash	X					X		X	0			X					B	FL	Change in type of operation		
92	13'10"s x 9'11"r x 180' L	X	X			X			X									C-1	SD			
37	13'10"s x 11'9"r x 92' L	X	X		X								0			0		B	FL			
59	13'10"s x 11'9"r x 108'L	X	X			X				X	X		X		X			D	FL			
9	14'3"s x 8'11"r x 100'L Squash	X			X				0		0			0				A-1	FL			
18	Same by 100'L	X				X			X	X	X			0				C	FL			
33	Same by 98'L	X		X	X				0	0								A-1	FL			
34	15'6"s x 13'10"r x 154' L		X		X					X								B	FL			
84	Same x 130' L	X	X	X	X				0		X							B	BT			
96	Same x 108' L	X	X			X			X	X								B	SD			
3	16'2"s x 14'10"r x 214' L	X	X	X	X											0		A-1	BT			
4	Same by 216' L	X	X			X			X									C	BT			
20	Same by 116' L	X	X		X											0		A-2	FL			
35	Same by 120' L		X		X													N/A	BT			
42	Same by 158' L	X	X	X	X				0									C	FL			
97	Same by 180' L		X			X			X		X		X					E	BT			
41	16'7"s x 10'11"r x 74'L Squash	X	X	X	X											0		A-2	FL			
58	Same by 150' L	X					X	X	X			X						C-1	BT	Constant Erosion		
23	17'2"s x 15'8" r x 136' L	X	X		X											0		D	FL			
108	17'3"s x 16'6"r x 124' L	X	X	X			X		X									A-2	BT	Extensive Main- tenance Required		
98	20'5"s x 13'10"r x 210' L	X	X	X		X			X	X	X							A	BT			
(24)	SUBTOTAL	22	17	8	13	8	3	1	X-10 0- 6	5 3	4 2	1 1	3 1	2	1	1	4					
									STOCKPASS SIZE CIRCULAR PIPE													
46	72" x 88'			X	X					0								A	BT			
56	72" x 108'			X			X						X			X		B	TP	Neighbor uses		
16	84" x 68'	X			X				0		0						0	A-1	FL			
21	84" x 62'	X		X	X											0		B	FL			
11	84" x 132'	X		X	X				0									B	BT			
12	84" x 176'	X		X	X				0	0	0							A-1	BT			

CASE STUDY NUMBER	UNDERPASS IDENTIFICATION BY SIZE & LENGTH	INTENDED USE			ADEQUACY FOR UNDERPASS USE				FACTORS AFFECTING ADEQUACY MENTIONED BY LANDOWNER X = Severe Enough to Limit Use; 0 = Not Serious Enough													REMARKS
		LIVESTOCK	VEHICULAR	DRAINAGE	ADEQUATE	LESS THAN ADEQUATE	INADEQUATE	UNUSE	SOME FORM OF DRAINAGE	SNOW	ICE	INADEQUATE SURFACING	UNDERSIZED	LOCATION ON PROPERTY	LARGE HERD SIZE	OWNER'S ATTITUDE	NONE TO SPEAK OF	SEVERANCE SITUATION	TOPOGRAPHIC LOCATION			
13	84" x 162'	X		X				X					X			X		B	BT	Possible Utility		
50	84" x 124'	X		X			X	X	X	X			X	X				B	BT	Difficult Access		
57	84" x 85'	X			X					0								A-2	BT			
44	90" x 96'			X	X				0	0								A-2	FL			
45	90" x 134'			X	X				X		0							B	FL			
1	96" x 210'	X				X							X	X				B	SD			
7	96" x 168'	X		X		X			X	X			X					X	BT			
55	96" x 92'	X							X	X								X	SD			
93	96" x 128'	X		X	X				X		0							X	BT			
105	96" x 110'	X		X				X								X		B	BT	Possible Utility		
106	96" x 120'	X		X	X												0	A-2	BT			
63	108" x 276'			X	X				0		0							A	BT			
14	108" x 170'L	X			X				0									B	BT			
54	108" x 212'L	X		X		X			X	X								B	BT			
8	120" x 132'L	X		X			X	X	X									B	BT	Continual Creek Flow, Deep Pools		
11	120" x 148'L			X	X												0	B	BT			
107	120" x 156'L	X		X			X		X	X								B	BT	Too much drainage		
62	132" x 439'L			X			X		X									B	FL	(Creek)		
25	SUBTOTAL	17		19	13	4	5	4	X-7 0-8	5 4	5		5	2		3	4					
					VEHICULAR SIZE CIRCULAR PIPE																	
17	156" x 154'	X		X	X							0						B	FL			
85	162" x 150'	X	X		X				0	0	0							B	TP			
86	162" x 150'		X	X		X			X	X	X							B	BT			
83	180" x 176'	X	X			X			X	X								D	BT	Inadequate for the main user		
87	180" x 326'	X	X			X			X		X							B	BT			
88	180" x 180'		X	X	X					0								B	SO	Oversized for size of farm		
95	180" x 116'	X	X		X					0								B	SO	Approach road snows in		
99	180" x 240'	X	X			X			X									A	BT			
89	180" x 124'			X	X				0		0							A	BT			
9	SUBTOTAL	6	7	4	5	4			X-4 0-2	2 3	2	1										

CASE STUDY NUMBER	UNDERPASS IDENTIFICATION BY SIZE & LENGTH	INTENDED USE		ADEQUACY FOR UNDERPASS USE							FACTORS AFFECTING ADEQUACY MENTIONED BY LANDOWNER X = Severe Enough to Limit Use; 0 = Not Serious Enough													REMARKS
		LIVESTOCK	VEHICULAR	DRAINAGE	ADEQUATE	LESS THAN ADEQUATE	INADEQUATE	UNUSED	SOME FORM OF DRAINAGE	SNOW	ICE	INADEQUATE SURFACING	UNDERSIZED	LOCATION ON PROPERTY	LARGE HERD SIZE	OWNER'S ATTITUDE	NONE TO SPEAK OF	SEVERANCE SITUATION	TOPOGRAPHIC LOCATION					
								CONCRETE	BOX	STRUCTURES														
94	14's x 10'r x 44'L	X	X		X			0									B	FL						
110	14's x 10'r x 44'L	X	X		X			0									A-2	FL						
30	16's x 12'r x 123.5'L	X	X		X			0		0							A-1	FL						
31	16's x 12'r x 123.5'L	X	X		X											0	A-1	FL						
32	16's x 12'r x 123.5'L	X	X		X			0									A	FL	Height is of some concern					
43	16's x 12'r x 110'L		X			X						X			X		C-1	FL	Depends on farm machinery width					
90	16's x 12'r x 44'L	X	X		X				0	0							B	SD						
71	16's x 14'r x 123'L	X	X		X											0	C-1	SD						
72	16's x 14'r x 55'L	X	X		X											0	A-2	FL	Owner wanted more clearance					
91	20's x 14'r x 44'L	X	X			X			X	X							C-1	BT	Mostly winter vehicular problems					
73	16's x 12'r x 125'L	X	X		X											0	A-2	FL						
⑪	SUBTOTAL	10	11		9	2		X- 0-4	1 1	1 2		1			1	4								
⑨8	TOTAL	85	37	37	55	25	11	10	X-28 0-25	18 17	9 12	1 3	10 2	3 2	2 1	7 1	17							
																			TOPOGRAPHIC LOC.					
*	As % of Total	87%	38%	38%	56%	26%	11%	10%	X-29% 0-25%	18% 17%	9% 12%	1% 3%	7% 2%	3% 2%	2% 1%	7% 1%	17%		39 Flat 38 Bottom 18 Side 3 Top 98 Total					
*	Those described as both inadequate and unused are counted twice, thus the total is 104% rather than 100% in the adequacy totals.																							

It would be safe to assume for any one given severance situation, there is at least a 50% probability a structure under consideration would be adequate. Likewise, there is also near a 50% probability of marginal or no utility. This judgment, during justification studies, would be tempered by specific problems; but before a ranch study ever gets to that state, it would be well to keep this in mind. Probably more important is the fact that eight out of ten structures do have a probability of some usage in land management. This is because the categories of adequate and marginally adequate total about 85%.

Because of the possibility of the size-length relationship, it is important to include this discussion on utility for stockpass size structures. To begin with, we must consider a two-dimensional question: Is utility a function of opening area and length? If this is so, it should be possible to isolate variables which would not noticeably affect the usability. For example, a seasonal stockpass considered adequate would cause the weather variable to be isolated because the landowner has indicated this was adequate for his usage and any accompanying drainage problem was not paramount to him. Location was generally suitable if he gave the stockpass a favorable rating, which would allow us to hold that variable constant. Type of livestock operation and severance situation have some bearing on the landowner's opinion of the stockpass. Usually, if he is satisfied with it, the cattle are using it and it has not noticeably changed his method of operation or management and it is considered adequate. By virtue of holding these variables constant, we explore the concept of utility with respect to size and length. A common denominator for measurement is to divide the opening area by length.

Weighting the average for adequate Type "A" and "B" stockpasses on primary and secondary roads shows a fairly constant area/length factor from .37 to .44.

Inadequate or marginally adequate stockpasses indicated a factor of about .40 which would tend to indicate utility is not dependent on size and length. Reasons of low usage on these usually included drainage difficulties (5 out of 26 structures) and eliminating this variable as a factor in most cases would have rendered these same "A" and "B" stockpasses as adequate. From our research, topographical location was the strongest variable which played a part in changing the utility of this type of stockpass and supports the analysis of Chart #3 and data sheets of pages 31-34.

Without a larger number of samples in each category of usage, it is not wise to use the multiple regression technique on correlation of variables to test the significance of the affect of one variable upon another. The universe number is somewhat less than 1,000, and collection from half of this yielded finished research reports on 98 structures. However, testing 17 adequate round pipes for a correlation coefficient in simple regression, where area opening was correlated to the independent variable length, showed a correlation coefficient of $R = .35$, indicating no correlation.

About the only conclusion to be drawn from the question, "Is utility a function of opening area and length?", is that it is only in the most severe of cases, as shown by small, long stockpasses, where cows and calves cannot be herded through. Such stockpasses would have an area/length ratio of less than .25, meaning the lower the figure, the less the possibility that stock will use it of their own free will or be herded through. This is based on the following case studies:

#1 - 96" x 210' long, which has a factor of .23 - Barely Adequate

#13 - 84" x 162' long, which has a factor of .23 - Inadequate & Unused

#50 - 84" x 124' long, which has a factor of .31 - Inadequate & Unused

#56 - 72" x 108' long, which has a factor of .26 - Inadequate

Weighted average = 84" x 151' long = .25 -- these were all circular pipe.

These figures, although they represent a small part of the total sample, are one-fourth of the circular pipe 72" to 96" in diameter. Nine of the seventeen in this category are judged adequate at an average length of 106' and area/length ratio of .40. The remaining marginally adequate pipe averages 144' in length and have a utility factor of .36. Narrowing down the small, long pipes to the above-listed case studies, gives us a weighted average and arithmetic mean of .25, showing a significant difference from the overall average of .40. All thirty-four round pipes (including vehicular underpasses) averaged 10' in diameter x 162' long, with a high area/length ratio of .48. One important comment from the Butte District was that the principal objection to stockpasses by landowners arises over the length of small passes. Another memorandum from this district mentioned that the agents assigned this project were of the opinion that any future installation of circular stockpasses under 10' in diameter would not be adequate for stockpass usage. This opinion is shared by the other right-of-way agents. Most important, the larger size allows cleaning of the structure by a scoop or farmhand for use in wintertime.

FARM USAGE

There were thirty-five vehicular underpasses sampled. The predominant need for a large structure is on the Interstate System due to the fact large equipment can cross over the non-controlled access highway. The majority of structure need was for the cattle-raising unit, rather than for the farm unit. Few (less than 5%) of the sample showed combination units, which would have farm implements crossing as well as stock and other normal vehicle usage. There can be some estimates made as to the typical equipment needed for a diversified unit. For example: One 1,830 acre wheat, oats, barley, hay and cattle ranching unit

showed the following equipment and frequency of usage:

1. John Deere 4020 Diesel, 9' wide and 9' high, with Farmhand and attachment 7' wide and 7' deep, and a 12' hay basket. Tractor crosses highway a minimum of twenty-five times a year.
2. John Deere 14' cultivator, 15'8" wide (actual measurement), crosses five to six times a year.
3. International Harvester 12' one way, 14' wide, to be replaced by a tandem 14' disc.
4. Four section harrow, 21' wide.
5. John Deere rod weeder, 16'4" wide, two round trips a year.
6. International Harvester 14' press drill, 14'8" wide, three round trips a year.
7. John Deere 14' self-propelled combine, Model #55, 14' high x 16' wide, crosses two times a year.
8. GMC 1959 grain truck with stock rack. Three tiers of hay over the top of the stock rack gives this 15' height.
9. Hesston 280 swather, 14' wide, six to eight round trips a year.
10. Small Allis-Chalmers tractor and mower, six to seven round trips per year.
11. Ford tractor and Massey-Harris baler, ten to fifteen round trips per year.
12. New Holland stack cruiser, 70-bale retrieving capacity. Loaded, is 12'2" high x 9' wide x 23' long. It makes twenty trips a day when hauling straw.
13. Morrell side-delivery Farmhand rake, 13'2" wide.
14. GMC pickup truck used in all phases of operation.

Average large equipment height was about 14' with a maximum of 15', maximum width was 16'4". He also hauls cattle through once a year with a double-deck Semi. He runs approximately 170 head of cattle, pastured mostly on one side of the highway, but calves on the opposite side. This requires three round trips a day for observation and feeding during the calving season. Wintering requires

hauling hay across the highway to the cattle at least two times a day.

This is not necessarily typical or average for a diversified agricultural unit; however, it is reasonable to assume this is a necessary inventory of farm equipment in order to process justification of a sizable structure (20' span x 16'4" rise) and should provide some insight as to equipment in actual use. Frequency of highway crossing will vary with the severance situation. This particular ratio of underpass cost to farm appraisal would be about 10 to 20 per cent.

The average number of cattle per unit sampled was 220 head, or about 190 animal units. The median was 155 with a range of 8 to 1,600 animal units, excluding one large grazing association.

The average size unit was 3,400 acres with a median of 1,500 acres and range of 138 to 45,100 acres, excluding the same large grazing association, which was not a very typical unit. This indicates a carrying capacity of 17.9 acres per animal unit year, on the average, which tells us the units were all of fairly high productivity.

PART IV

PHYSICAL CHARACTERISTICS AND SUGGESTED CONSTRUCTION CRITERION

1. Physical Characteristics

Maintenance: A memorandum was sent to each of the five districts inquiring as to the maintenance problems and costs. The following replies provided insight into continuing costs connected with the livestock and vehicular underpass.

District #1 - Missoula

Only one stockpass had been cleaned in three years. Change in land use had caused a great deal of runoff and silt in the metal tube. This was then cleaned with an old two-horse slip and loader which is less than 6' wide. No plant mix was placed in existing underpasses because this was done primarily during construction. The costs were insignificant.

District #2 - Butte

Only a few isolated cases have been experienced involving maintenance services of combination drainage and stockpasses where sediment has been removed, and in such cases, a combination truck-slip-cable would be used to drag material into or out of the pipe and spread it. The method used was a combination truck-pulley-slip through the structure with the truck and cable drum on the roadway with a pulley block rigged up on the edge of

the stockpass to pull the slip through. The district engineer expressed the opinion that no asphalt would be laid within an existing corrugated pipe which had been used to such an extent that sand or other bedding would be in the bottom of the pipe and, therefore, would not adhere. Existing treated timber structures are inspected often because of fire hazards that may accumulate due to weeds and other debris. Probably the most noticeable accumulation of sand, sagebrush, rocks, etc., occurs when the underpass has fallen into a condition of non-use.

District #4 - Glendive

The maintenance supervisor was asked about general maintenance and costs for the various pipes in this district. He stated that if the pipe design was for drainage and/or other use, they do not maintain the pipe at all - other than to prevent any flooding or washing hazards. Apparently, snow problems are strictly up to the landowner except that some snow fence has been put up in several places to help the blowing problem.

There were no figures available as to average annual per pipe maintenance costs, but it appears to be a very minor item.

Insofar as maintenance appears to be an individual problem, the various landowners that have been interviewed have used front-end loaders and/or slips on long chains to clean out the pipes or to resurface the pipes that have washed out. The division

construction engineer mentioned that on those pipes surfaced after construction, the blacktop is hauled into the pipe with a front-end loader and spread by hand to surface the floor of the pipe.

District #5 - Billings

In reference to the inquiry regarding maintenance problems, the investigator contacted the maintenance supervisor and the maintenance foreman at the Miles City Division several times while working the Miles City area on stockpass research. There are two large underpass drains on Wayatt Coulee, Rosebud County, and another in Custer County, that have had several maintenance problems. These problems consisted of snow removal, ice build-up, washing out on the lower end, and the washing in of foreign materials. The maintenance cost of equipment, man hours and repair materials was estimated to average from \$500.00 to \$600.00 per year. This figure was dependent on the type of year in which these costs could rise considerably due to heavy rainfall and/or heavy snow fall.

The above-mentioned large 17'3" span x 16'6" rise stockpass in Custer County has been a very expensive structure. This structure has caved in twice. The maintenance people tore it out and lowered it the first time; the second time, they repaired it by taking it completely apart and it was redone at the manufacturer's direction. It is even now beginning to settle and fold in again. A lot of the clearance was lost when this struc-

ture was lowered, as it has had to have additional material placed in the bottom, and silt with gravel washes in, making it extremely muddy when wet. The cost of materials, equipment and man hours has cost the maintenance forces approximately \$28,000.00 to \$30,000.00; however, should the structure go again, it will become the manufacturer's problem as they supervised the last repairs and it was done to their specifications. The maintenance forces have cleaned this structure out several times but there was no estimate of cleaning costs available. In conversation with the maintenance supervisor, a possible solution to this problem was a drain pipe alongside with drainage channels cut into and out of this flat area to handle the runoff.

There are several other structures which are stockpass-drains with which the maintenance people in Miles City Division have experienced problems. Three of these structures were in the Research Study. The first was a 96" concrete pipe and the second a 15'6" span x 13'10" rise C.M.P. underpass, the third mentioned in the above paragraph. The problems experienced have been that when these structures, and some others, were installed, the material placed in the bottom was only gravel. As silt and water wash through, the build-up becomes a soggy, muddy mess and renders the structures unusable. As the owners complain to the highway maintenance people, they have gone in and hand cleaned the structures, taking out all of the silt and gravel and then hauling in an oil mix or plant mix,

if available, then wheeling it into the structures by wheel barrow. This gives the bottoms a firm, flat surface for stock to walk on that would not become wet and boggy. The maintenance foreman said that they are in the process of redoing two more such structures between Miles City and Baker on Highway #12. They slope the pavement to one side to allow for drainage on that side and reasonably dry walkway on the other.

The oil mat costs between \$6.00 and \$10.00 per yard for the material, depending on the distance of the haul. The costs were estimated to vary from \$250.00 to approximately \$450.00 per structure, depending on the size of the pipe, the equipment required, and the amount of hand labor involved. This would be either a small circular pipe or "A" or "B" arch-type stockpass.

The maintenance work and expense of underpasses in the Lewistown Division was discussed with the maintenance supervisor. He stated that they had not had too much actual maintenance work; however, they had worked on at least seven stockpasses on new roads where there had been no provisions made for surfacing of the bottoms. He stated that it usually took four men two days to do what cleaning was required and wheel the surfacing in and tamp it. Also, the use of one truck for two days and the material or oil mix would run approximately \$7.00 per yard. The length and size of the structures would have to be considered in the amount of yardage required for surfacing. He felt the ones they

had done would probably average four to five yards of mix.

His estimate is as follows:

4 men @ 2 days	=	8 @ \$30.00 per day	=	\$240.00
1 truck @ 2 days	=	2 @ \$32.00 per day	=	64.00
5 yards @ \$7.00 per yard			=	<u>35.00</u>

Maintenance total to repair a mat in structures	=	\$339.00
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Using the above figures, it is quite apparent that it would run approximately \$325.00 to \$350.00 per structure for an oil mix mat for a small size stockpass. Large structures would require as much as 80 yards of plant mix. He also stated that they have several structures with gravel bottoms that they have had to haul some gravel into as some of the material had washed out with heavy runoffs. He did not have any figures on this work and he felt it was quite minor. Most of the structures they have worked on have had no further complaints from the owners. He said he did not know whether they were satisfied or had just given up.

In the Billings area, maintenance problems, the work of maintenance forces, and expense on the underpasses were discussed.

- The maintenance supervisor stated that most of their maintenance work had been a one-shot deal, such as repair of washing by use of rock, etc. He considered this a very minor problem with probably not more than \$700.00 per year overall cost on all structures.

He further stated that on major drain-stockpass and vehicular

pass combinations it seems only feasible for a smaller drain structure to be placed in beside the larger structure to carry away the minor drainage. This would be especially beneficial during the winter months when there are small spring flows and periods of snow melting that drain water into the main structure, thus causing a build-up of ice and slush.

Further discussion with the two maintenance foremen indicated agreement with the supervisor on their maintenance problems and they had no specific information on any major costs on any particular structure.

The conclusion was drawn that there are some maintenance problems on most all of our large major drainage underpass structures. The supervisors of the Lewistown and Miles City Divisions were able to give the best breakdown of cost of maintenance of specific structures. These costs can vary on the type of winter and summer runoffs, also the type of material placed in the bottom of structures or those structures not surfaced during construction.

There are two pages of winter photographs, taken January of 1971. This was a follow-up on some structures known to have snow problems. A snow storm had occurred the previous week, and then a warming trend. The resulting effect was such that the cold winds hit the melting snows and formed a hard crusted surface on the snow. This makes the snow very difficult to handle without a scoop or farmhand. Any snow to be shoveled away from the stockpass is done by hand or small one-horse slip. These two stockpasses generally cannot be used in winter,

and the management has subsequently located stock water on both sides of the right-of-way for wintering cattle. Winds were generally from the north and west in the area of Mile High pass.

Photos on page 48

The ice inside the pipe had apparently broken from a warming trend, which melted the ice and lowered the water level by runoff. It is still dangerous footing for livestock and would not be considered usable in this condition. This underpass was also blocked by snow.

Photos on page 49

A plywood door was used to keep one entrance from completely drifting in by the north wind and the south entrance was shoveled clear enough for usage.

Photos on page 50

These photos represent the worst in mud and drainage conditions (Case Study No. 108), and entrance erosion (Case Study No. 104). They are included to show actual evidence of a necessity to completely analyze the drainage requirements separate from stock or vehicular requirements.



NORTH ENTRANCE

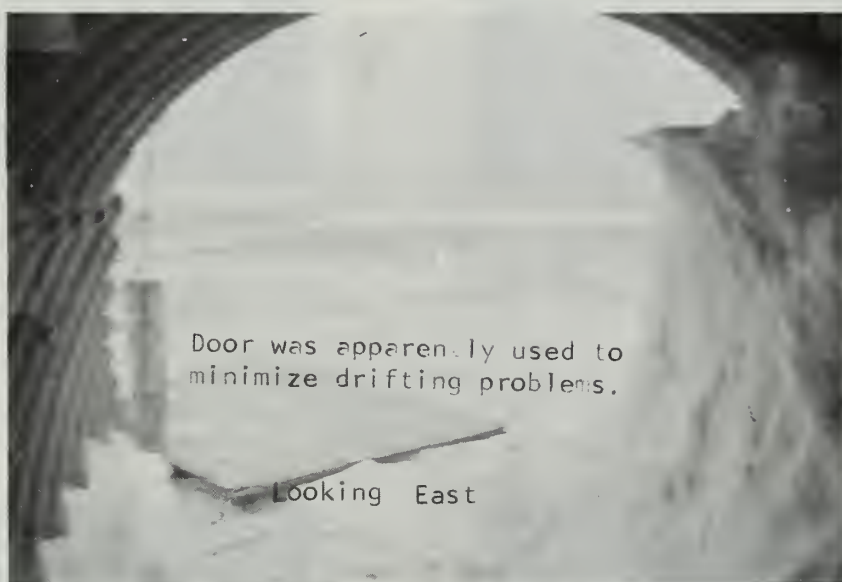
Type "B";
5'10" span x 7'7" rise



SOUTH ENTRANCE: Notice
drifting pattern.



Inside of pipe
looking NORTH
Ice has broken
from lowering
water level.



DRAINAGE AND EROSION EXAMPLES

Case Study No. 108
17'3" span x 16'6" rise x 124' long
Arch C.M.P., Stock-vehicle-drainage



NORTHWEST ENTRANCE-- Mud Conditions



SOUTHEAST ENTRANCE-- Mud Conditions

Case Study No. 104
7'3" span x 11'5" rise x 110' long
Squash C.M.P.; Drainage used for stock



Pavement Erosion at Outlet



Pavement Erosion, Notice Drainage Channel cut.

2. Suggested Construction Criterion

Metal Pipes: The specifications engineer provided the original insight to metal pipe installation, in reference to torque tests. It was his belief that not all bolt heads could be put on the inside of the pipe to eliminate the possibility of cattle or other stock injury on the protruding threaded bolt ends. This bolt end was found to be enough of a problem for stock, to further explore the situation. The hydraulics division agreed the torque tests (bolt tightening) were not completely feasible on the outside, most of all those located on the bottom of the pipe. The bolts and nuts were designed for both the hollow and the rib of the structures. Placement and torque depends on what the construction specifications call for. One manufacturer's representative mentioned that there was some flexibility of the structural plate installation. Most of the corrugations are the 6" x 2" design, as shown in Montana Standard Drawing 59-00. See photo, middle of page 49, (left side of pipe) for correct installation. The following were suggested as alternatives:

One possibility: Bolt heads on the outside up to about one-half of the actual height of structure, and bolt heads on the inside to the top of the structure. From a structural standpoint, it is immaterial whether the bolts are on the inside or outside, and this would lessen chances for injury to stock. The sequence in which the bolts are tightened is the most important thing. If it became necessary to keep the bolt heads on the outside, the thread end could be cut off flush with the nut on the inside. This would increase labor costs somewhat. One 17'3" x 76'6"r, 3 miles west of Manhattan, was found to have all bolt heads on the inside, rib and hollow. Several others have since been located.

Another alternative: All bolt heads placed on the inside except on the bottom plates. Cost comparison on a bid call would help determine whether the construction unit cost would increase.

The same manufacturer's representative also suggested that the standard 10-gauge was heavier than need be in areas of shallow fill on the arch "A" and "B" type stockpass. A 12-gauge would be sufficient here, depending on the fill height. There could be as much savings as 10% of the steel costs. Also, gauge requirements could be more closely analyzed in other livestock and vehicular underpasses to get the most for the money. The 1969 and 1970 bid tabulations, however, reflect a wide variety of gauge specifications, most probably showing concern for proper design. Highway designers tend to slightly heavier gauges to be on the safe side. This manufacturer changed their arch pipe design after some field installations (one specifically mentioned on page 43) showed too flat a radial arc on the arch portion, causing the pipe to bend inward and collapse. The slight change in this radii apparently improved the structural deficiencies. The collapse was not attributed to too light a gauge of metal, but insufficient fill as well as the radii of the arch.

There have been some drainage areas (about 2 out of 100) that have eroded the asphaltic surfaces of a combination structure. One recommendation by the same manufacturer's representative was to tie a wire mesh to the floor bolts and use cement for the floor mat, much like a building floor. This would be needed only in extreme circumstances. Perhaps some entrances should be built to specifications similar to those in a concrete lined canal and covered with "blown asphalt" (corrosion-proof membrane for metal pipes). These would adequately handle drainage, stock and vehicles.

"Blown Asphalt" - Floor Surfacing of Metal Pipes: Our Materials Division recommended this corrosion preventive material for use in the stockpass on the paved surface. It was specifically asked of them to suggest something soft but not sticky and which would withstand heat and cold as well as provide a reasonably 'punky' footing for livestock. This would have to stick during periods of heavy drainage, yet not melt and run during warm weather nor crack in cold weather. Blown asphalt has a high melting point and resists low temperatures. This suggestion seemed most reasonable and economically feasible if it were blown on at the same time the pipe was coated. Due to the fact this non-corrosive lining is sprayed only in extreme cases where acid soils necessitate it, most structures would not require it. The cost was estimated comparable to asphaltic pavement; however, the extra haul from Wyoming was mentioned as a possible cost factor. This was the best available solution to eroding paved structure surfaces and overcoming the problem of livestock refusing to walk on the pavement. This also cushions the sound in the pipe which normally would spook the cattle in some of the larger echoing structures.

Concrete Box Culverts: Whereas these are generally the most successful structures for all around usage, they are considerably more expensive. Actual numbers were only 11% of the total sample. Costs can easily run one-third again as much as the arch pipe. Most of those installed years ago on the Interstate System are a bridge-span box with no floor. There were basically two types of footings depending upon foundation requirements. The barrel, or piling footings, for unstable conditions and spread footings in the more stable areas. The barrel footings have the advantage of allowing an extra 2' of clearance by excavating the dirt floor, without severe damage

to the structure. This has been done in one case on a 16' span x 14' rise box, and backfilled after a timber sale and logging operation. Another landowner expressed the desire to do so to allow passage of a stockliner (livestock van) that will not navigate the vertical curve down into the structure. The spread footings would not be able to withstand this and there would most likely be structure failure of some sort, if not complete collapse. The district engineers should be consulted by the user in situations which might alter the structural strength of the structure. It is a possibility, however, that the user might not contact anyone. It is not an identical situation to a three-span bridge where there are pilings a greater distance apart and there is no height or width problem. Where economically feasible, the square or rectangular concrete box with stabilized approaches and footing material (manure build-up often works well where no drainage occurs) is the most sound and usable (but most expensive) structure. This is based on the experience of the states of Utah, Nevada, Wyoming and New Mexico, as well as those case studies in Montana. We must take into account the Interstate System traverses areas of large public land holdings in these other states and temper our judgment by this.

PART V

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

The conclusions and recommendations arrived at are a result of judgment based upon case studies, field trips, district meetings, statistical analysis and any other pertinent information. They are not specifically documented with reference to case studies in all instances, but are intended to be a logical development of all the research findings.

One thing this study points to indirectly is the necessity for capable management on those ranch or farm units with structures of marginal usage. This is not to imply the burden of maximum usage lies with the operator himself but the fact that not all of these installed structures are going to serve the intended purpose leaves the landowner to many of his own devices. It is hoped that any part or all of this report will make right-of-way personnel and others involved aware of the many things the landowner and the right-of-way agent have to contend with and cause those personnel involved to make any reasonable added effort necessary for the landowner to better utilize the land use structure. The landowner should be made aware of the limitations as well as the possibilities. Many of the problems are not insurmountable; many are. The number of stockpasses in the seasonal usage category (8% of the total sample) indicates the number generally quite usable but impassable in winter. Locating these a short distance one way or the other would have made a difference in only a few cases with regards to snowfall or drainage. Those in a predominantly heavy snowfall area and at high elevations are usually "seasonally adequate". Combination drainage and stockpass struc-

tures are generally not as usable as two separate structures. In nearly all cases, separate structures would have been preferred, even though a property owner judged a combination structure adequate.

Whereas light and sound effects appear to have some influence on the use of the structure, it is not measurable. A good paved or gravel bottom in the corrugated metal pipe will deaden the echo, and the beveled end on the metal pipes provides more area opening for light than does the square end cut. One investigator observed a herd of about 200 head scatter when being driven under a wooden highway bridge and a large truck passed overhead. Seven men on horseback and a pickup driver had considerable difficulty rounding them up again. It is for this reason at least one other rancher preferred a metal pipe under some fill. They like the room and light the old wooden bridges provided but range cattle would normally spook and scatter if there was much traffic overhead.

The attitude of the user is important in the utility of the structure. Only one out of a hundred was not used because of spite; two out of a hundred would not use them because they did not think the structures were large enough and didn't even want to try to use the stockpass structure. The rancher or farmer who needs and wants an underpass will try to maintain it while the man who does not need it will not make much effort. There were both positive and negative feelings as to the actual utility of the structure. Some judged them adequate while not liking their land severed, and some judged them marginal or inadequate for reasons not completely evident.

Most of the structures had inadequate interior surfacing or approaches. Drainage was at some fault; however, foresight would have taken care of the most severe cases and the cost to cure would have been a very small per cent

of the total installation cost and subsequent maintenance costs. For the added expenditures, the structure would change from marginally adequate or inadequate to adequate, changing it to a higher utility and frequency of usage.

Drainage has shown to be a most important factor in determining utility. The Mississippi study found that "topographic location and drainage condition to and in the structure do not significantly control the usage, but do influence the attitude of the user." We have found similar results in one respect, that a rancher or farmer will make a greater effort to use a well-drained structure than a poorly-drained one. Drainage conditions can alter the terrain and erode the entrances to the extent that cattle and machinery cannot navigate into or through the structure. Large boulders, tumbleweeds, and wash-out at pipe entrances are visible in the case study photographs.

A cold wind can be quite harmful to livestock bunched up in a structure. Unless absolutely necessary, the structure should be fenced off in winter time. Cattle sometimes develop a summer time habit of using these for shelter. See recommendations for suggested gate types.

Another significant item in this study is the small number of ranch or farm operators who have had to make extensive innovations or changes in operation. About 10% of the questionnaires marked for this question showed some changes made. There were 9 out of 87 that made changes in the form of drilling wells, pasture diversion, moving cows and calves over the highway rather than use the underpass, and changes in agricultural usage on severed portions.

Ranchers expressed a preference for an underpass tall enough for a man on a horse to ride through, or wide enough for a pickup to follow the cattle.

2. Recommendations

These are based upon case study findings, statistical summaries, attitudes of users and investigators, and conclusions.

- 1) Justification of land use structures: Economic or safety justification should still be the primary criterion for underpass installation. If one cannot be justified for one user, seek alternative solutions with two or more users. The underpass should not be installed just to facilitate a settlement, but if the structure has 7 chances in 10 of being a usable underpass, extraneous circumstances may influence the decision to install the structure. We cannot expect 100% efficiency from these structures, as witnessed by this study, nor can we expect to be 100% correct in analysis of necessity.

Where possible, comparable situations from our case studies can be used to determine the type and size of pipe. For example, suppose there were a ranch severance similar to our summer pasture severance situations. By using this as a primary area of comparison, one can tabulate all those structures in that situation. From that list, it can be further narrowed down by size of unit and carrying capacity, and whether there is free herd movement or herding to summer pasture. There should be two or three good comparables to use to determine a good usable and adequate structure. There may develop a range of acceptable sizes which then could be chosen by whatever

means available to the investigator. He would have (probably) good comparables of inadequate structures for the type of unit, as well as comparables of adequate structures.

2) Minimum Size Recommendations (See next page)

3) Fencing

Use proper wing fencing into the structure. Where bolt holes are open in the corrugated metal pipe, wire can be tied to these holes from the base post. This will keep cattle or calves from climbing onto the highway between the base post and stockpass. There are concrete headwalls which cover the bolt holes and make it virtually impossible to tie wire or fasten a pole to. These should be left open to tie into. On a concrete structure, the base post can be placed flush on the structure wing wall. It will often be desirable to place a long pole on the ground alongside the fence to prevent cattle leaning into and damaging the wing fence during herd movement. Some ranchers prefer a pole wing fence. This can be constructed by extending the horizontal poles past the base post right up to the top of the beveled end of a metal pipe. In no event should the stock be allowed to climb up and around the stockpass or concrete wing wall. This has resulted in stock injury in at least two cases out of a hundred. Gates should be properly installed in those stockpasses where necessary. A wooden hinged gate works well for the "A" or "B" type of arch cattlepass. In other cases, either a wooden gate or wire fence with stays works quite well. Long poles are too heavy and cumbersome and do not hold up under a lot of usage, unless extremely well constructed. Long wing fences at the proper angle would accommodate a sizable herd for the larger underpass.

2) Minimum Size Recommendations:

	Length	Round	Arch	Squash	Box	3-Span Bridge
Vehicular	Any length	144"	10'10½" x 9'11"*	12'8" x 8'7"*	12's x 12'r*	24's x 14'r
Stockpass	Up to 100'	96"	A or B 6'11" x 8'6"	10'11" x 7'11"	6's x 6'r	-----
		120"				
	100 to 200'	(180")**	(15'8" x 15'r)**	12'8" x 8'7"	10's x 8'r	-----
		144"				
	200 to 300'	(180")**	10'10½" x 9'11"	13'4" x 10'4"	(12's x 12'r)**	-----
Over 300'		(180")**	(15'8" x 15'0'r)**	16'7" x 10'11"	(12's x 12'r)**	-----
		156"	12'2" x 11'0"		12's x 12'r	
		(192")**	(17'3" x 17'0'r)**		(16's x 14'r)**	
Vehicular and						
Stockpass	Any length	144"	12'2" x 11'0"*	-----	12's x 12'r	24's x 14'r
Sheep (small bands)	Up to 100'	84"	A or B 6'11" x 8'6"	10'11" x 7'11"	4's x 5'r	-----
	100' to 200'	96"				
	200 to 300'	120"				
Large bands	Up to 100'	120"	10'10½" x 9'11"	13'4" x 10'4"	8's x 8'r	-----
	Over 100'	144"	13'10" x 12'2"	14'3" x 8'11"	10's x 10'r	-----

The box and squash sizes are not conclusive from the study. We do have information provided by other states, indicating the box sizes are appropriate. The squash sizes are based upon limited information from our study. The above sizes can be dependent on whether there is herding or free movement. Herding requires larger sizes.

* Be cautious on vehicle size requirements.

** Herds greater than 200 head.

4) Stockpass Corrals

If a structure is used for free cattle movement, no corrals would be necessary. However, corrals at the cattlepass should be constructed to handle small herds. Unless it is a very large structure, herd drives are often lengthy and tedious. An underpass that allows at least two cows abreast will work better than a narrow one for herd drives. For the herd drive, a large holding corral (100-300 head); (200' square is suggested as a minimum size); in conjunction with a small herding corral (20-25 head); (40' square is suggested as a minimum size); may serve the purpose most satisfactorily. This is to keep the cows and calves together. Our experience and study shows the larger underpass will not need a holding corral. These would be upward of 12' in width and 10' in height in the arch pipe category, 10' x 10' in the concrete box category, and 15' in diameter in the circular pipe category.

5) Entrance Stabilizations

Other than the subject "Suggested Construction Criterion" of Part IV, few further construction recommendations will be made with regards to the cattlepass. To expand the subject somewhat, entrance stabilization will vary with the type of soil, amount of drainage, and area to be paved or riprapped. A truck load of gravel is seldom the answer in an eroding situation. Soil samples should be taken and appropriate pathway design developed. The flatter backslope should be seeded with native grasses, and the steeper backslopes riprapped and perhaps concrete in the headwall area. To prevent erosion undercutting, the ends should be set in concrete.

6) Methods to Get Cattle Through the Stockpass

Mature cattle will more readily use a stockpass than will a calf or yearling and this is particularly true of the small structures. Small herding corrals and small numbers at a time (about 20 head) are recommended for these situations. Dairy cows or bulls can be and have been trained to lead range cattle through. This works primarily on the smaller ranching units, less than 200 head. A pickup with feed in the back has been used, by two of the ranchers interviewed, to lure cattle through an underpass. Many devices have been tried and failed, and often an exasperated rancher will watch cattle wander through on their own after futile attempts at driving them through. It is worth the effort to scatter hay and salt through the structure or whatever feed might lure the livestock through. In a stock-to-water situation, cattle will use a small pipe (7-8' in diameter) up to 500' in length to get to water. These are very rare cases, however.

7) Drainage and Icing Problem Solutions

One effective solution to the icing up of a stream in a combination structure in use during the winter months was such: The rancher broke the ice, spread sufficient straw, and there was fairly secure footing for the livestock when it froze over. This would not be a sufficient solution to a situation where the water is pooled and deep. An old two-horse slip and chain are used to clean the snow, dirt or mud out of the smaller structures, as well as spread gravel or dirt in them. The larger vehicular size structures will accommodate a front-end loader. Manure leaves a good solid bottom where drainage is not a factor. It

also has been spread to start cattle through the structure. Small chip gravel ($\frac{1}{4}$ " to $\frac{1}{2}$ "') with a large amount of fines provides a very good base for cattle. Where possible, combination usage of a single structure for both stock-pass and drainage should be avoided. If there is any doubt about a specific problem, contact the district maintenance supervisor. He will most likely recall a similar situation and offer reasonable solutions. Paved surfaces are necessary in combination drainage stockpasses.

8) Topographical Considerations

Flat, Top, Sidehill and Bottom locations for underpasses are most usable, in that order.

9) Machinery Considerations

Measure all farm and ranch machinery to get accurate overall measurements. These will differ from brochure dimensions. A minimum of 10% over the maximum width and height of machinery with highest necessity and frequency of usage is recommended for adequate clearance. Where winter time usage is desired, a pipe should be large enough to accommodate a farm-hand or scoop.

10) Damage Mitigation and Ultimate Utility

The livestock or vehicular underpass will not necessarily mitigate all damages. In many cases, damages can and should be paid over and above what the structure costs because there is only a 54% probability it will be adequate, all things considered. There are 85 chances out of 100 it will be used and show some degree of adequacy -- this means 85% will have some utility. This is, hopefully, an aid to the right-of-way agent who

sometimes finds himself struggling with the paradox of mitigating all damages in order to justify the cost of the structure.

11) Arch Pipe Versus Squash Pipe

The squash C.M.P. (span greater than rise) has a more potential snow problem than an arch of equivalent pipe periphery where rise is greater or slightly smaller than span. This is because of the lower profile. The squash does have a width advantage for a comparable pipe periphery.

12) Responsibility of Maintenance

On a combination drainage-stockpass, the landowner should be advised who has the responsibility of maintaining the structure.

13) Justification and Non-contiguous Units

This study did not elaborate on the non-contiguous unit because it was considered too vague a variable (page 19); however, more needs to be said on this subject. Considerable experience gained through this study plus our experience through years of structure installation leads us to arrive at the following recommendation: With due respect to the legal problems and decisions involved, it is recommended non-contiguous units be considered for structure justifications when it is all part of the same ranching operation.

14) No hard and fast rules can be stated that will relieve the agents and designers from careful consideration of all the factors involved.

FOOTNOTES & BIBLIOGRAPHY

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